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Mechanical and Engineering Section.

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Rolled-Steel Car Wheels.

BY SAMUEL M. VAUCLAIN,
Superintendent of Baldwin Locomotive Works.

The requirements for car wheels have risen very rapidly during the last few years, and wheels which were at one time satisfactory are now taxed beyond their limit by the more severe service which is expected of them. The loads upon the wheels have increased from 50 to 100 per cent., whereas it has been impossible to increase the weight of the wheel in a like proportion because the limiting factors, such as frogs, switches, etc., were fixed before the modern 100,000-pound-capacity car came into use.

The manufacturers of chilled cast-iron wheels have been very successful in meeting the demands which have been made upon them, careful design and selection of the best mold and approved method of casting have accomplished much. The chilled-iron wheel is distinctively an American

product, and we have occasion to feel proud of the achievements which have been made in the developments of this wheel. But the brittleness of the flange, inability to resist the heating effect of the brake shoe, shelly treads (as shown in *Fig. 1*), producing flat spots and the internal stresses induced in the casting of such a wheel have created a field for a wheel which would be free from these objections. This demand has been met by the introduction of the steel tired wheel, such wheels are manufactured with both plate and spoke centers. Steel-tired wheels of many designs have been made, their centers being of cast iron, cast steel and wrought iron and of both plate and spoke form. Those of wrought iron being very difficult to produce cheaply, to meet the competition of the world, because of our high-priced labor.

FIG. 1.—Sample of shelled tire.

Fig. 2 shows three stages of the process of making wrought-iron spoke centers. The spokes are made by bending pieces of iron in the form of a triangle, these are fitted into a round ring, the hub is then filled with iron and the wheel is heated and hammered under dies. *Fig. 3* shows two stages of the manufacture of wrought-iron plate centers.

Standard wheels of the types so well known and in use for several years under passenger and other high-priced equipment are too expensive, at least they are so considered, to put under freight equipment.

Even these wheels suffer from shelly spots on the tires, or a variation in the density thereof, unless the utmost care and expense attend their manufacture.

Fig. 4 shows an etched section of a defective tire and of a good tire, the good tire being dense and perfectly homogeneous, whereas the defective tire shows a structure which is not uniform in density and which contains other structural defects.

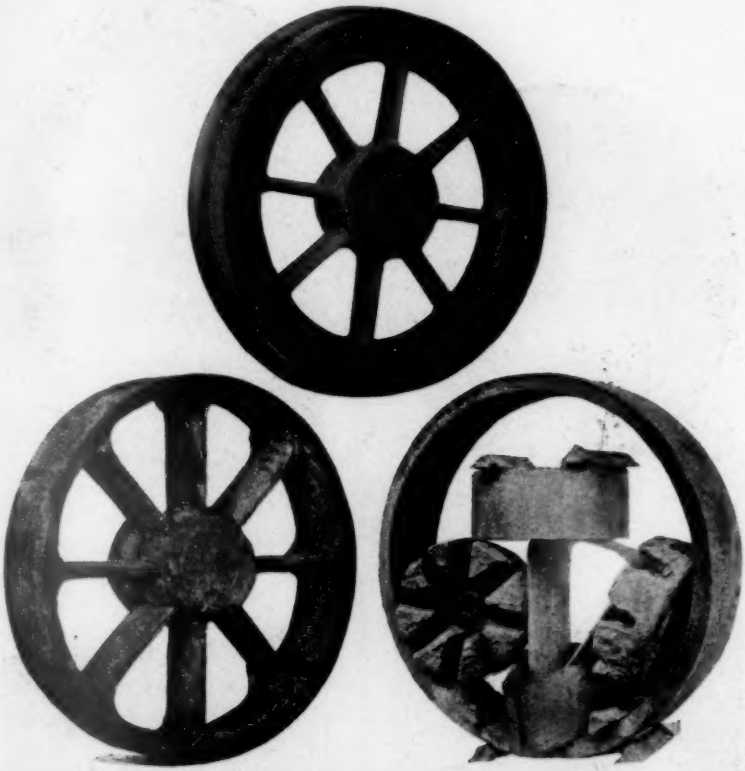


FIG. 2.—Forged steel-tired spoke wheel.

It is thus we find an aching void in the wheel business. We must be able to produce a wheel, safe, durable and sufficiently low in price to compete with and eventually supersede the chilled cast-iron car-wheel that has so long held sway in this country.

Fig. 5 shows the etched section of a long ingot. This is the base of all processes necessary to make a first-class solid forged, high carbon, rolled steel wheel, cheap enough

to compete with cast-chilled wheels, and good enough to compete with the high-priced steel-tired wheels. The process of manufacture is simple; the ingot is cut into sections, as shown on *Fig. 6.* Each section is of sufficient weight to make a wheel, and the upper or segregated section is discarded.

FIG. 3.—Forged plate steel-tired wheel.

FIG. 4.—Section of good and poor tire.

Fig. 7 shows this process, the ingot being handled by an immense and powerful manipulator, or mechanical man. This device is almost human in its action, reaching into the furnace, taking out a blank and deftly putting it under the

press. Each of these sections is then pressed into shape under a huge 5,000-ton hydraulic press, the blanks being handled by mechanical means, as shown in *Fig. 8.* From there by overhead cranes the blank is transferred to the

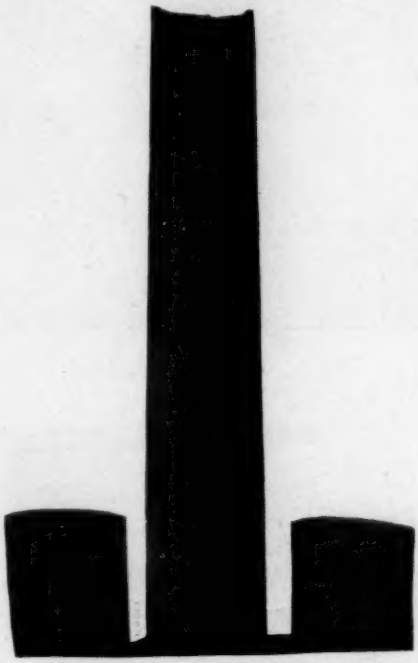


FIG. 5.—Cross section of ingot.

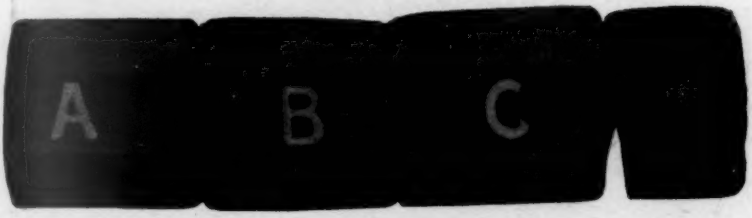


FIG. 6.—Blooms from which wheels are rolled.

rolls, where it is subjected to enormous pressure and revolved at a high rate of speed, emerging a perfect wheel.

The method of rolling and arrangement of rolls is shown in the diagram on *Fig. 9*, from which it will be seen that

FIG. 7.—View of manipulator.

FIG. 8.—View of 5,000-ton press.

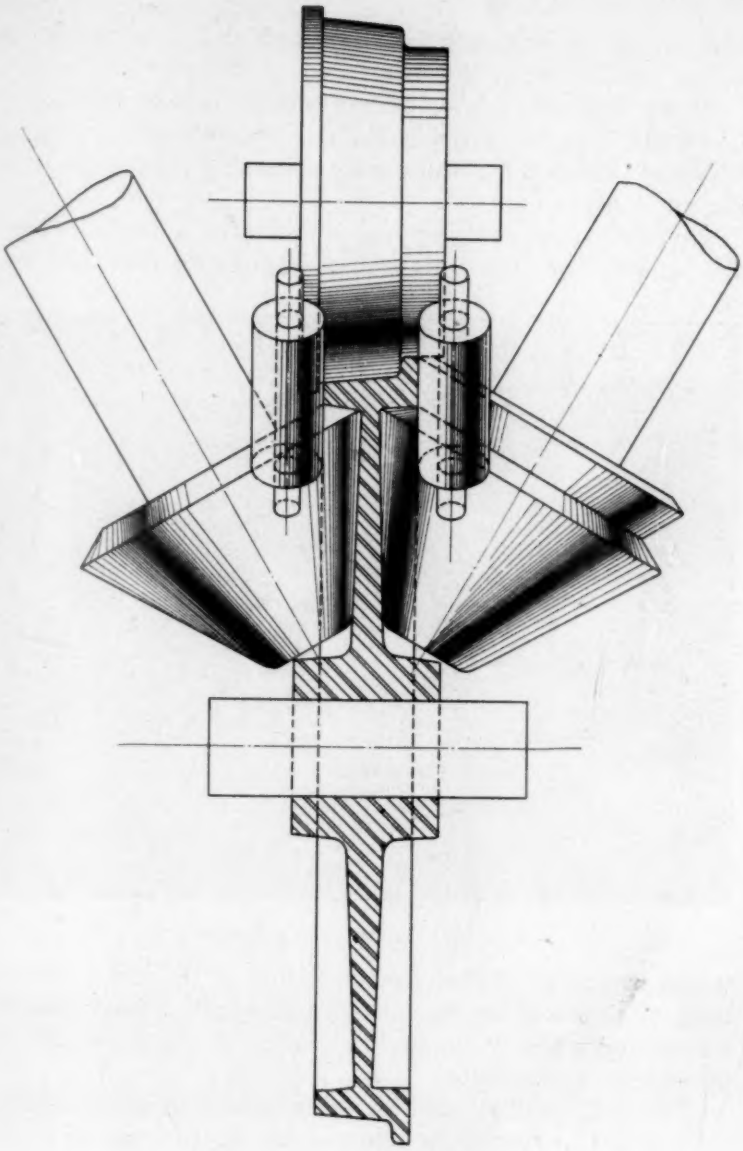


FIG. 9.—Diagram of rolls.

the arrangement is such that thorough and heavy work can be put on the tire of the wheel.

If we desire the plate of these wheels to be of the dished or curved form the same is easily accomplished by placing it in the 500-ton press and gently squeezing it into shape, as shown in *Fig. 10.*

Fig. 11 shows three etched sections of a forged wheel, the quality of the material is unquestionable and the

FIG. 10.—View of rolling machine.

wheel possesses all the characteristics of the good tire and none of those of the defective tires, which I have already shown and which I am again showing on the screen for the purpose of comparison.

The judgment formed by an examination of the etched section is confirmed by the results of the physical and chemical tests.

Fig. 12 shows sections of wheel from which drillings were taken for analysis, the results are surprisingly uniform and indicate the greatest uniformity in the wheel. Tests

CHEMICAL ANALYSES.

Test.	Carbon.	Silicon.	Phos-phorus.	Man-ganese.	Sulphur.
Flange	·610	·268	·043	·87	·050
Tread . . .	·614	·268	·042	·90	·048
Face . . .	·620	·267	·041	·86	·052
Rim	·614	·270	·042	·91	·052
Plate . . .	·602	·265	·043	·89	·051
Hub	608	·265	·042	·86	·048

PHYSICAL TESTS.

Test.	Size of Test.	Elastic Limit.	Ultimate Strength.	Elonga-tion.	Reduction of Area.
	Inches.			Per Cent.	Per Cent.
Flange . . .	2 x ·619	50,300	126,600	12·0	19·0
Tread	2 x ·619	50,600	124,600	10·0	12·0
Face	2 x ·619	52,600	121,000	10·0	13·0
Rim	2 x ·619	52,000	121,300	12·0	16·3

CHEMICAL ANALYSES.

Test.	Carbon.	Silicon.	Phos-phorus.	Man-ganese	Sulphur.
Flange . . .	640	·175	·042	·86	·050
Tread	·650	·177	·042	·86	·050
Face	·650	·180	·045	·86	·050
Rim	·654	·175	0·44	·85	·051
Plate	·660	·180	·046	·84	·049
Hub	·666	·180	·044	·84	·050

PHYSICAL TESTS.

Test.	Size of Test.	Elastic Limit.	Ultimate Strength.	Elonga-tion.	Reduction of Area.
	Inches.			Per Cent.	Per Cent.
Flange . .	2 x ·619	52,000	129,000	14·0	20·0
Tread . . .	2 x ·619	51,600	124,300	10·0	13·0
Face	2 x ·619	52,300	128,600	10·0	15·0
Rim	2 x ·619	51,300	124,000	11·0	16·6

have also been made by supporting the wheels horizontally upon a ring underneath the face of the tread and allowing

FIG. 11.—Etched sections.

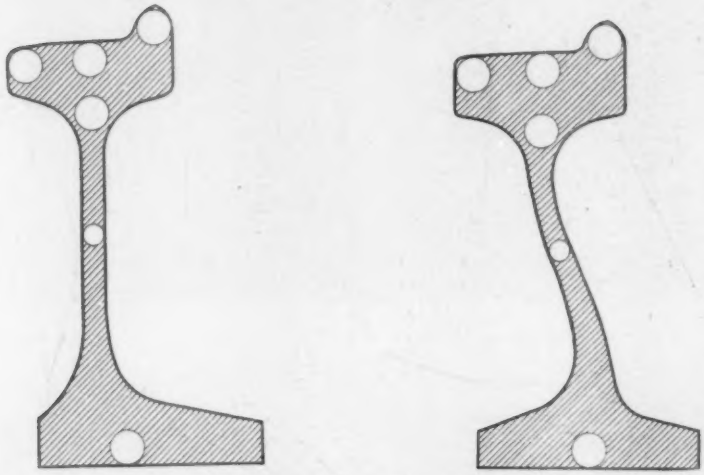


FIG. 12.—Results of chemical and physical tests.

a weight of 2,240 pounds to strike the wheel from various heights. It took thirteen blows to break a 36-inch wheel, eight of the blows being from a height of 30 feet.

Another wheel was tested in running position, and striking with a weight of 2,240 pounds it took seventeen blows, nine of them being from 25 feet, to fracture the wheel from rim to hub.

Fig. 13 shows a wheel after it has been subjected to this test and it at once illustrates the severity of the test and the ability of the wheel to resist any stress which it is liable to encounter in service. It is perfectly clear that the use of this wheel would banish broken flanges from the list of causes leading to wrecks and damage to property.

FIG. 13.—Rolled wheel after drop test.

One of the most severe tests that can be imposed upon the chilled-iron wheels is that generally known as the Thermal Test. This consists in pouring a ring of molten iron 1½ inches thick and 4 inches deep against the tread, no cracks to develop within two minutes. This test is designed to secure a wheel which will not crack by the heat developed by the application of the brake shoes, and it is considered by manufacturers of chilled-iron wheels to be a very severe

requirement. A number of rolled wheels have been subjected to this test without injury to them. The heat from a ring of metal 4 inches wide in place of 2 inches had no further effect than to cause the rim to expand and to draw the hub down slightly. No fracture was produced and the heat given out by the molten iron was sufficient to heat the tread for 2 or 3 inches to a dull cherry. After withstanding this test there need be no fear of breakages as the result of heating of the tread by application of brake shoes.

Now then as to the approximate value of these wheels as compared with cast chilled wheels of the very best material and manufacture. The comparison of the cost per 10,000 miles of the two types of wheels is shown in the following statement:

SOLID ROLLED WHEELS.

Cost of pair of rolled wheels	$54 00
Cost of four turnings	2 40
Cost of four removals and applications	2 40
	$58 80
Less scrap value	8 75
Net cost	$50 05

Mileage, 350,000.
Cost per 10,000 wheel miles, $1.43.

CHILLED-IRON WHEELS.

First cost of pair of chilled-iron wheels	$18 00
Cost of boring and mounting	80
Cost of removal and application	60
	$19 40
Less scrap value	5 80
Net cost	$13 60

Mileage, 80,000.
Cost per 10,000 wheel miles, $1.70.

It is usual for the railroads to determine the average cost of wheels by dividing the total yearly cost by wheel mileage made during that year. The statistics vary from 1·65 to 1·78, the average closely checking the foregoing estimate.

The natural field for the rolled wheel is:

(1) The severe service of engine and tender trucks, in which steel-tired wheels are now exclusively used.

(2) Passenger-car equipment, in which the element of safety plays an important part.

(3) Heavy freight-car equipment, for which the chilled-iron wheel has proved inadequate.

The wheels, however, are adaptable to lighter service, and statistics indicate that it would be profitable to employ them in street-car service.

The following statement shows the cost of maintenance of wheels in street-car service in various parts of the United

FIG. 14.—Rolled-steel wheels.

States. These figures are practically based upon the use of the usual type of chilled wheel:

	Per 10,000 Miles.
Northwestern	$1 61
Pacific Coast	1 15
Middle-West	2 14
Chicago	3 04
Canadian	3 04
Philadelphia	1 65

The roads carrying the greatest number of passengers will generally show the greatest cost, as the constant brak-

ing necessary because of frequent stops and slipping resulting from rapid acceleration is very hard on the chilled-iron wheel. By the rough usage at many crossings many wheels are put out of service by chipping off the flanges. The rolled wheels are entirely free from this defect and their adoption by street railway companies should prove to be very economic. Progressive street railway managers have been quick to recognize the advantages that the steel wheel possesses over a cast iron one, and even the greater expense of the solid forged steel wheel has not deterred its introduction, and it is the general opinion that marked economy has resulted therefrom.

FIG. 15.—Rolled wheels in service.

We are already making solid forged steel wheels for this service in large quantities.

Fig. 14 shows a group of solid forged and rolled wheels for railroad service, the fine appearance of these wheels can be seen from this photograph.

As the mighty oak had its origin in the small acorn, so the great railroad systems of to-day rest upon the stability of the flange of a car wheel.

Upon this small section of metal, about 1¼ inches square, depend the lives of millions of passengers and the value of merchandise of incalculable price. Passengers amid the comforts and luxuries of our modern service hardly realize

the vital importance of this piece of metal; but engineers and railroad managers do, and they have been directing their best endeavors to this most vital element of railroad equipment.

DISCUSSION.

MR. G. H. CLAMER:—Perhaps few of us, who are not directly connected with the operation of rolling stock, realize the large proportion of the railroad wrecks which are directly due to broken flanges. In former years when the equipment was light, speeds not so great, the cast-iron wheel did good service, but with the advent of the 100,000-pound capacity car, the cast-iron wheel, as formerly made, was found to be inadequate for the service. The old design of wheel was transformed, the flanges made as thick as possible, etc., but even so, they were found wanting.

The safety of the traveling public depends so much upon the wheel that railroad men have recognized for some time the desirability of using steel for this purpose. On passenger equipment it has become almost universally the custom to use a steel-tired wheel, but this is rather an expensive affair, and presents several defects which are perhaps not inherent in the wheel we see before us.

A steel wheel, forged directly from the solid ingot, at least, theoretically, presents the best kind of structure for the service. It is only a question of producing a wheel of this kind at a satisfactory price, and to show that it will compare favorably in operating cost with wheels now on the market, to create a great field for it. It is a difficult matter to make railroad people understand that an article which is high in first cost will be cheap in the end. This evidently applies to the product in question.

Mr. Vauclain has shown, although the steel wheels are softer than chilled cast iron wheels, nevertheless, the rate of wear is very much slower. The same holds good on bearing metals. It has long been the prevailing idea that it was necessary to have a hard bearing to resist wear, but that such is not the case has been amply proven by the fact that additions of large percentages of lead to the former copper and tin alloy has led to far better results, in not

only anti-frictional but in wearing qualities. This fact was first brought out by Dr. Dudley, who made long series of tests fifteen or twenty years ago, in which he compared in actual service the wearing properties of copper and tin and copper, tin and lead alloys, with varying percentages of the different metals. Without going into the details of these experiments, suffice it to say, the following general conclusions were reached:

(1) The lower the content of tin, the slower the rate of wear.

(2) The higher the content of lead, the slower the rate of wear.

We perhaps all know that tin added to copper greatly increases its hardness, but it will be seen that both these conclusions have been drawn from alloys which were softer than the one which had hitherto been used as standard, viz: copper and tin, with 10 per cent. tin.

If hard metal is used for bearings or car wheels, whichever it may be, the effect due to abrasion is, the particles instead of being elongated are flattened out before being worn off, and are simply broken down and split off at a rapid rate. There is no doubt of this, and it is only a question of time before this will be thoroughly understood.

PROF. A. E. OUTERBRIDGE:—In view of the contemplated substitution of rolled steel car wheels for chilled cast-iron wheels in freight-car service, I wish to ask Mr. Vauclain whether any comparative tests have ever been made, to his knowledge, of the difference in rolling friction on the rail between steel wheels and chilled cast-iron wheels?

My reason for making this inquiry is because I remember a case in point which happened a number of years ago. A coal mine located in a mountainous district was equipped with coal cars, carrying perhaps 10 tons each; these cars were drawn up grade to the mouth of the mine by the mine locomotives, and then ran by gravity down the mountain. The system of braking was very crude, simply "choking" and "skidding" a sufficient number of the spoke wheels, which were chilled cast iron. The number of wheels which cracked, especially in cold weather, caused by heating due

to the skidding, induced the proprietors to experiment with cast-steel wheels in place of chilled cast-iron wheels. They found, greatly to their surprise, that the mine locomotives could not pull as many loaded cars up the incline when equipped with cast-steel wheels as they did with chilled wheels, all other conditions remaining the same, and I was informed at the time that this difference was attributed to difference in friction between the wheels and the rail. The company decided not to adopt cast-steel wheels.

My recollection is that a locomotive pulled twenty-eight loaded cars equipped with chilled cast-iron wheels out of the mine without difficulty, and could barely pull twenty-six precisely similar cars equipped with cast-steel wheels, though I do not vouch for the exactness of these figures. If such a marked difference existed in the case mentioned, where the load on each wheel was comparatively light and the speed comparatively moderate, how much greater would it be in the case of the modern very heavy equipment and high speeds in freight service to-day?

A difference of 10 per cent. in hauling capacity of a locomotive, due to difference in rolling friction between steel wheels and chilled cast-iron wheels and the rail, would be a serious matter in freight-car service.

I am of the impression that it is an established fact that the brakes grip a steel wheel more tightly than they do a chiled cast-iron wheel at equal pressures, due to difference in friction.

MR. J. S. WHITNEY:—What is the weight of a 33-inch rolled steel wheel designed for same service as a 600-pound 33-inch cast chilled wheel?

MR. VAUCLAIN:—About 675 pounds.

MR. WHITNEY:—What Mr. Outerbridge has said suggests another observation and inquiry. The wear of the *tread* of a well chilled cast-iron wheel is due to the action of the brake, which in time removes the surface, and if the metal is not of proper quality, causes "shelling out." The rolling of the tread over the rail does not cause wear, unless there is not sufficient depth of chill, or the chill is too soft. But the wear of the *flange*, which is more important as to

safety, is due to the friction of the side of the flange against the side of the rail, which reduces the thickness, and tends to breakage. As the steel tire must be of the same quality throughout, and can be no harder than is consistent with strength, while the chilled wheel can be made hard on tread and flange while the body of the wheel is soft and strong, it has always been found that the flange wear is greater in the tire than in the wheel, under same conditions. This, of course, makes necessary several re-turnings of tire, to form new flange.

I would ask, what is the experience with the rolled-steel wheel, having, as Mr. Vauclain says, an almost uniform chemical analysis, in this respect?

MR. VAUCLAIN:—A consideration of the various resistances which a locomotive overcomes in hauling a train will at once show that the rolling friction of the wheel plays but a minor part in the total resistance of the train. The total resistance is composed of that due to head or wind, to journal friction, to curvature, to acceleration or overcoming the inertia of the train, and to the grade, which is usually greater than all the others combined. The resistance due to these items is all independent of the rolling resistance of the wheel.

In designing engines no attention is paid to whether the cars of the train are to be equipped with chilled iron or steel-tired wheels, and an extensive series of experiments which I made upon train resistance as well as those made by various railroad companies have failed to show any difference in drawbar pull of a train equipped with steel-tired and chilled-iron wheels respectively.

The wear of the flange is usually greater than that of the tread, because in the former case there is sliding as well as rolling friction, whereas in the latter there is rolling friction only and the abrasive effect of the former is much greater than the latter. While the rolled wheel is of a uniform analysis the strength increases with the hardness. The ductility, however, decreases with the hardness, but no matter how hard the wheel be made, its ductility will always be greater than that of a chilled-iron wheel. The physical

tests which I have made show this clearly, giving a tensile strength of 120,000 pounds per square inch against 35,000 pounds per square inch for a chilled-iron wheel. The flange wear of rolled wheels is the same as that of a steel-tired wheel, which is generally recognized to be less than that of chilled-iron wheels. In opening the discussion Mr. Clamer has clearly shown that a good wearing metal is not necessarily a hard one, and I have personally known tires to wear rapidly not because they were too soft, but because they were too hard.

RECORD HIGH-PRESSURE GAS WELL.

A gas well in the Nineveh region of Greene County, Pa., has shown what may be said to be the highest pressure ever observed in any natural gas well. The well struck the Campbell's Run oil sand, and, though the volume of gas was relatively small, the rock pressure finally passed the limit of the gauge, which was 1,500 pounds per square inch, and blew off the 2-inch pipe by which the well was shut in. As this pipe was supposed to be tested to 2,000 pounds, the ultimate pressure shown by the gas was probably not less than 1,600 pounds per square inch. A well in Lewis County, W. Va., has a record of 1,125 pounds per square inch, which is the highest known in that State.—*Iron Age.*

STEAM TURBINES FOR BALTIMORE ELECTRIC POWER.

An interesting feature of the recently announced developments in Baltimore electric power is the exclusive adoption of steam turbines as the prime mover. A contract recently closed by the Baltimore Electric Power Company with the Westinghouse Machine Company provides an initial equipment of 4,000 kilowatts in two generating units of 2,000 kilowatts each. A Westinghouse electrical equipment, complete and modern in every particular, has also been contracted for. Officers of the company state that the power plant will embody the latest developments in steam and electrical engineering. Being located outside of the congested districts of the city, all the boilers and heavy machinery will be on the ground floor. Floors and roofs will be of steel-concrete construction. The steam turbine plant will operate with a boiler pressure of 175 pounds and a superheat of about 100° F. A high vacuum condensing system will be installed, capable of sustaining a vacuum of 28 pounds at full load on the plant. The plant in its entirety has been designed on the separate unit plan, which virtually consists of a number of distinct power plants placed side by side, each entirely separate from the other, but each capable of helping out the other in case any link in the system should be disabled. This holds good through the entire apparatus, from the coal pile to the customer's building. In addition to this precaution against interruption of service, which is thus insured, the company will install a large storage battery which will

ordinarily "float" on the system. The construction work is already under way and will be pushed as rapidly as possible in order that the plant may be complete in all respects and running smoothly by July next.—*The Iron Age.*

ELECTRIC FURNACE CONSTRUCTION.

An interesting example of the introduction of electro-chemical methods into old industries is offered in the manufacture of pure artificial corundum. The Norton Emery Wheel Co., an old-established firm, with its main works at Worcester, Mass., purchased, several years ago, from the Ampere Electrochemical Co., the patent of C. B. Jacobs for fusing bauxite in an electric furnace, thereby producing a pure artificial corundum. The fused charge is allowed to cool slowly, when it acquires the hardness of corundum and the toughness of emery, and is suitable for wheels, stones, and all the various uses of an abrasive. The process is worked in a plant of the Norton Emery Wheel Co. at Niagara Falls. A rather extended and interesting exhibit at the St. Louis Exposition showed that the process is in a state of very healthy development.

A patent granted on November 22d to A. C. Higgins, general manager of the Norton Emery Wheel Co., is evidently intended for the special purpose of making artificial corundum, or, as it is called, alundum; but is of more general interest since it shows how, by judicious furnace design, any special refractory lining with its troubles may be avoided. His furnace consists essentially of an iron shell forming the outside of the crucible with suitable means for applying water on the outside of the shell to all its parts in a continuously flowing stream or blanket, and conducting it away at the base. The portion of the charge in immediate contact with the cool shell solidifies and thus forms a lining for the rest of the molten mass. The lining consists, therefore, of solid alundum. Similar linings have been used with success in other electric furnace industries.—*Elec. World.*

GAS TURBINES.

It was inevitable that the success of the steam turbine should lead to an investigation of the problem of the gas turbine; for it is natural to argue broadly that the results obtained with one gas will be obtained with any other, unless, indeed, some radical difficulties inherent in the gas or in the mechanism employed for its expansion should be found to stand in the way. The prospects for the early development of the gas turbine were discussed recently in a paper read before the British Institute of Mechanical Engineers, and, according to the author, those prospects are not very bright. Of course, one of the chief difficulties is the high temperature of the gas, which necessitates, if the temperature is to be reduced to a degree that is not injurious to the cylinder, the carrying away of a large amount of heat by the cooling water. If it were attempted to dispense with cooling water, or to use only as much as would cause a moderate reduction of the temperature, the rotating parts of the turbine would have to run red hot, and there is no material known to the engineering art to-day that would hold together at such high temperature, if subjected to the great centrifugal forces that would be developed.—*Scientific American.*

THE FRANKLIN INSTITUTE.

Stated Meeting, held Wednesday, January 18, 1905.

A Menace to the New York Harbor Entrance.*

By Lewis M. Haupt, C.E.

"These restless surges eat away the shores
Of earth's old continents; the fertile plain
Welters in shallows, headlands crumble down,
And the tide drifts the sea-sand in the streets
Of the drowned city."

From "A Hymn of the Sea."
Wm. Cullen Bryant.

At the Buffalo meeting of this association, in 1886, the writer had the honor of submitting a paper on the "Problem of the New York Entrance," in which was set forth the peculiar physical conditions existing on the bar stretching from Sandy Hook to Coney Island and suggesting a method of so modifying the ebb current passing out at Gedney's Channel, as to increase the depth by natural erosion.

At that date the limiting depth in this, the deepest natural channel, was 23·3 feet at mean low water, which, with a mean tide of 4·8 feet, gave 28·1 feet at high stages, so that vessels drawing 27 feet have passed over it at extreme high water, prior to improvement by dredging. In 1884 a report was submitted to Congress urging the enlargement of the channel to a width of 1,000 feet and depth of 30 feet by dredging at an estimated cost of $970,000, as follows:

Improving Gedney's Channel for 30 ft., M.L.W. . . 700,000 c. y., @ 50 cts.
Improving Main Channel for 30 ft., M.L.W. . . . . 1,550,000 c. y., @ 40 cts.

and it was expected that these channels would be "self-sustaining for many years." The Board of Engineers dissented from this view, however, and stated that it had "little expectation that anything more than temporary relief could be obtained from dredging on a bar exposed to the

*A paper read at the annual meeting of the American Association for the Advancement of Science, held at Philadelphia, December 26–30, 1904.

'full force of the Atlantic, and hence cannot recommend that method for a permanent improvement." It therefore suggested a dike extending in a S.-S.E. direction from Coney Island at a cost of about $5,000,000 or $6,000,000. As this dike would have closed the Coney Island, Fourteen Foot and East Channels and would have reduced the tidal ingress, it was not built, and the method of dredging alone was adopted. The board was fully cognizant of the fact that the sand was being moved from the adjacent shore of New Jersey and Long Island into the Lower Bay, as indicated by the spits at Sandy Hook and Coney Island; but the extent of this movement does not appear to have been very fully considered, although an important factor in the relative cost of creating and maintaining the channels. Especially is this true in view of the greater demands which modern vessels are exacting as to capacity and draught. Instead of 30 feet depth and 1,000 feet width, there are now required 40 feet and 2,000 feet, respectively.

It has also been found necessary to maintain the 30-foot channels by dredging at an annual charge of about $50,000, with no resulting increase of depths, so that in 1899 the project of opening a more direct channel via the East or Ambrose passage by dredging to a depth of 40 feet and a width of 2,000 feet was approved by Congress, provided the cost should not exceed $4,000,000 for the removal of the 42,500,000 cubic yards then in place.

Under the 30-foot projects the amount expended up to July 1, 1904, was $1,967,111.82, or about $1,000,000 more than the estimate even at the very high unit prices of 40 and 50 cents per yard.

Under the 40-foot project, to same date, there has been expended $1,223,498.52, and "11,944,131 cubic yards have been removed." From this statement it appears that the general cost has been 10¼ cents per yard in the Ambrose Channel.

In the report of the board, composed of Generals J. C. Duane, Henry L. Abbot and C. B. Comstock, three of the most experienced members of the Corps of Engineers, it was stated that the movement of sand towards the New

York entrance was manifested by the "form of Sandy Hook, a sand spit about 5 miles long, which has been slowly built during past ages by this northward movement of sand along the New Jersey shore. It appears to have reached a limiting length . . . and in the last 145 years its length has varied only about 2,700 feet. . . . An examination of the charts of Coney Island show that its western end is moving westward as sand is moved to it, the motion of its 18-foot curve amounting to 800 feet between 1835 and 1881."

Unfortunately this report does not appear to state the probable amount of material carried on to the bar by these two littoral movements. It is to set forth the great importance of providing for this menace to the entrance in the near future that some attention will be given to it in this paper. While physicists may be more especially interested in the vertical movements of the earth's crust as suggested in the recent paper of Prof. J. W. Spencer on the "Submarine Great Cañyon of the Hudson River," these internal forces do not appear to have sensibly affected the depths of the channels for commercial purposes within the range of modern records, so that the investigation of the volume and rate of drift will be confined to its horizontal littoral transportation.

For this purpose the British, Dutch, Swedish and Spanish charts of the early explorers and settlers of the seventeenth century are found to be of no value, being apparently merely a collection of itinerary sketches of the general conformations of the coast, as seen from their vessels. Neither are movements which have passed their climaxes and reached a condition of equilibrium, or which are undergoing a transition under the new conditions which previous cycles may have imposed, as exemplified in the successive hooks which characterize the peninsula of Sandy Hook, where the third reflex spit is now forming.

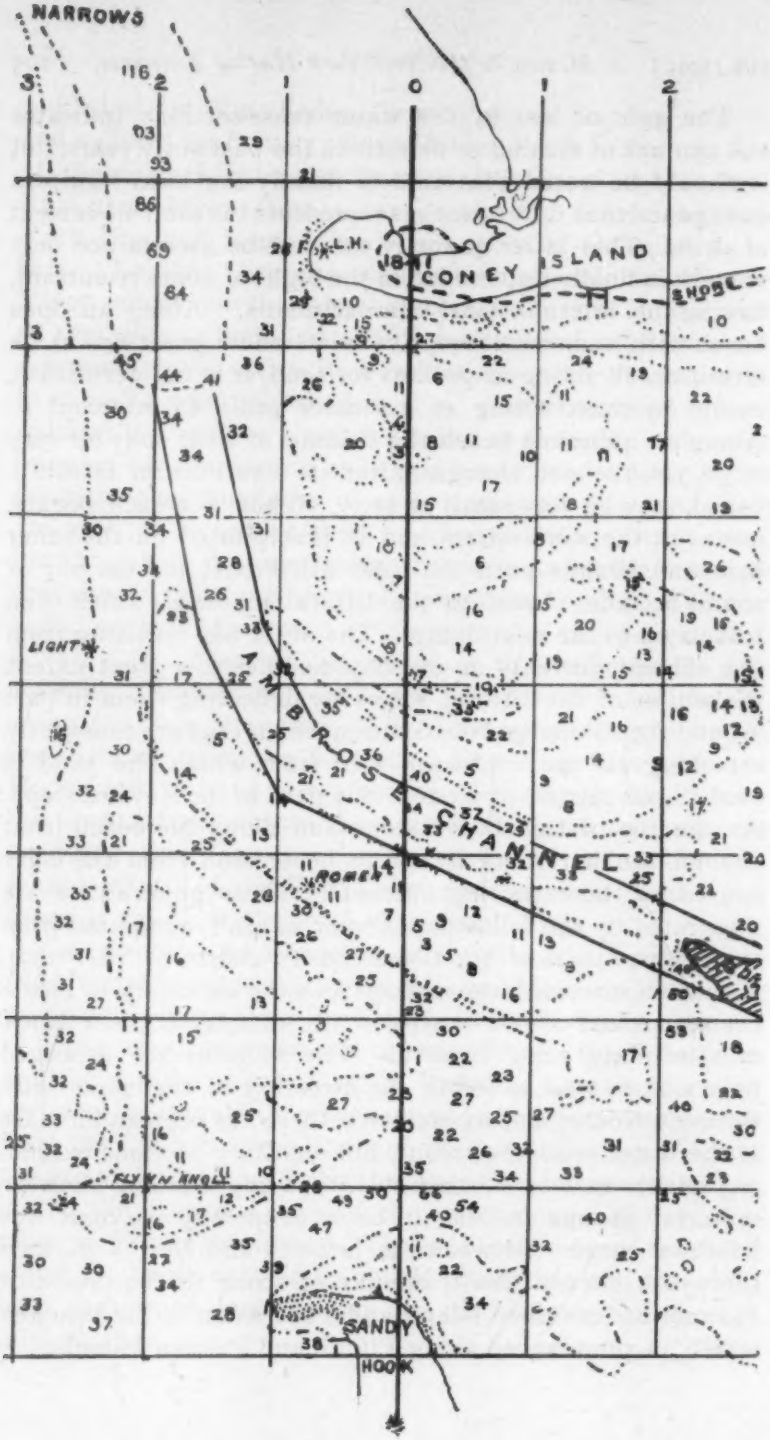
Data.—An early colonial map of 1626 shows Sandy Hook under the name of Goodwin's Point, after whom the Lower Bay was also named, but it gives no geographical positions. The first charts of value for comparative study to which the writer has had access are those in the American Atlas,

published by Wm. Faden, Charing Cross, London, in 1779, and collated by British officers during the Revolution. One of these, by Lieutenant Bernard Ratzer, of the Sixtieth Regiment, drawn from a survey of 1769, shows the New York Bay and Long Island on a scale of 6·6 miles to an inch. Another, being a detailed survey of the Hudson River and its mouth, published October 1, 1776, is on a scale of 4 miles to an inch, and a third, by Claude Joseph Sauthier, representing the entire State in sections; scale about 5 miles to an inch; was published in 1779. These three have been reduced to the same scale of 5 miles to the inch and superimposed for comparison as to position of shore lines. The discrepancies, smallness of scale and uncertainty of dates are such as to render them of comparatively little value, but they show the progressive movements of the inlets to the bays on the south shore of Long Island and the opening and closing of the breach at the mouth of the Shrewsbury River, N. J. Also the beginning of the outer beach, now covering "Rockaway Neck" and Jamaica Bay, and threatening the New York Bar. The State map of 1779 makes the distance from the Battery of New York City to Sandy Hook Light only 14 miles, instead of nearly 17 as given by the Coast Survey charts, thus discrediting its accuracy and confining this investigation to the later and absolutely reliable charts of the U. S. Coast and Geodetic Survey and those of the U. S. Corps of Engineers.

Co-ordinates.—As a basis of orientation the Sandy Hook Lighthouse is taken as the origin, since its co ordinates are practically identical on the British and American charts.

The axes of reference are the meridian of the lighthouse and the parallel of 40° 20′ 35″ N. latitude. On this meridian and parallel therewith, cross-sections have been constructed from the Coast Survey charts of 1841 and 1901, by dividing the arc of latitude into minutes (or 4,620 feet intervals) and taking the sectional area of the water extending for a distance of 3 knots southward. The area thus covered extended about 7·5 knots east and 3 south, embracing the traveling bank in front of Jamaica Bay and reaching beyond the old inlet of 1841.

The gain or loss in the water cross-sections indicates the amount of erosion or deposit in the past sixty years, but it should be noted that this is merely the local resultant change and that it by no means represents the total movement of drift. This latter quantity can best be ascertained only when it is finally impounded in the bight of some re-entrant, having no internal, tidal compartments. Along an open beach with numerous receptive inlets and a great bay at its terminus, all acting as pockets for sand, it is indeterminate, except by constructing an extensive groin to intercept it. Along an unbroken beach the volume of drift may be very large, yet the net changes, after its equilibrium is established, may be very small or zero. When a breach occurs, however, the sand enters and is precipitated on the inner bars and islands until the inlet drifts past and the bay or sound becomes closed to the littoral material, which then travels on to the next dump. The outer bar resulting from the effluent currents of the bay modifies to a great extent the action of the littoral forces by deflecting them in part around the submerged obstruction which they are constantly attacking on the windward side from which the sand is eroded and carried by a circuitous path to the leeward slope. At the toe of this latter slope and along the beach front beyond the bar there is apt to be erosion from the eddy caused by the returning currents. These generalities are illustrated by the following tabular exhibit computed from the cross-sections of the Coast Survey charts of 1841–1901, with such intermediate sections as were necessary to locate the scarps and counterscarps of the channel at these dates, or after sixty years interval. The sections are arranged from east to west to follow the direction of the movement. Between Nos. 7½ and 10, inclusive, there has been an increase of the water section or scour, but auxiliary sections extending farther east to Rockaway Life-saving Station show no material change, unless it be a deepening beyond the 5-fathom curve. Between the Jamaica and New York Bars there has been a small amount of scour in the flood-tide channel under Coney Island and a recession of the beaches which is pronounced along Plumb and Pelican Islands. A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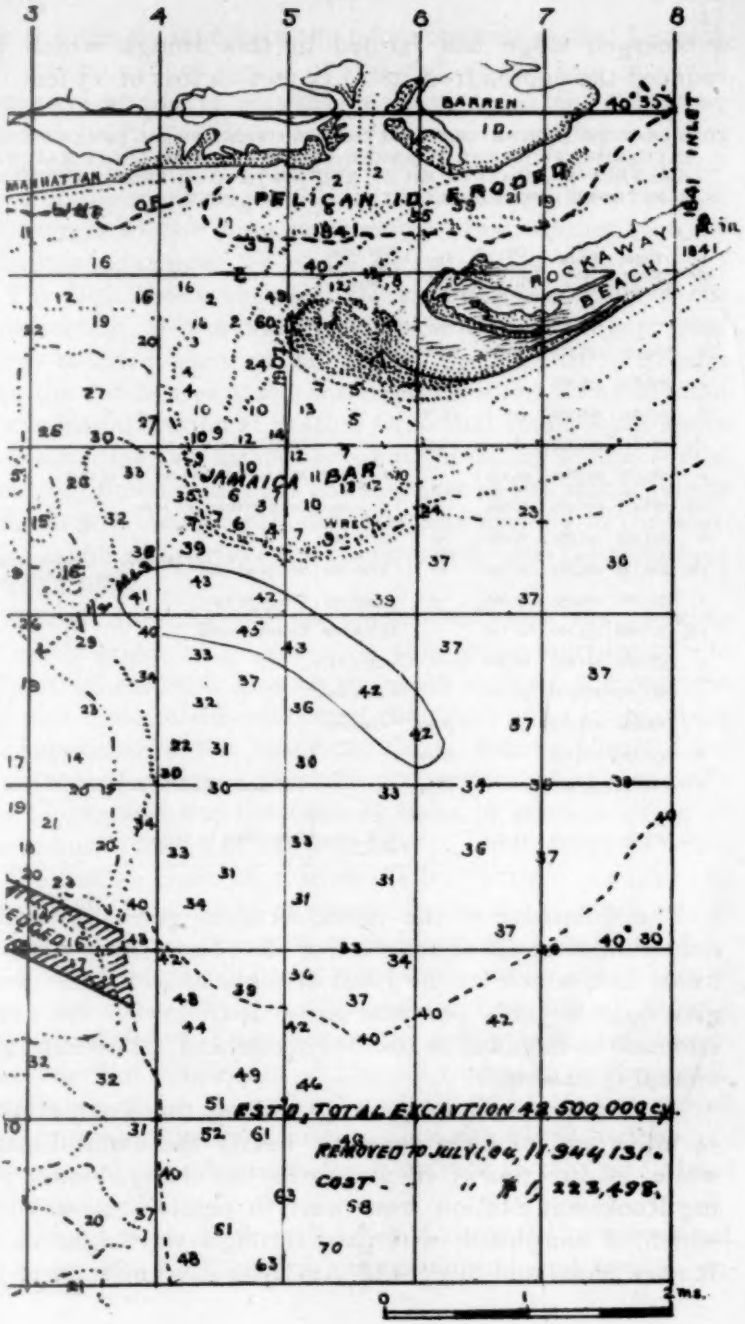
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submerged ridge has formed in this trough which has reduced the depths from 28 to 15 feet—a loss of 13 feet.

COMPARATIVE MARINE CROSS-SECTIONS OF VICINITY OF JAMAICA INLET, EXTENDING FROM THE MERIDIAN OF SANDY HOOK LIGHT EASTWARD 46,200 FEET' 8·75 STATUTE MILES, AND SOUTHWARD FROM LATITUDE 40° 35' N. THREE KNOTS. FULL INTERVAL = 4,620 FEET.

No.	Date 1841 Sq. Ft.	Date 1901. Sq. Ft.	Decrease. Fill — Sq. Ft.	Increase. Scour +.	Volume. Cub. Yds. Deposited.	Remarks.
10	384,635	433,323	—	48,688	—	—
9	256,829	338,381	—	81,552	—	—
8	241,847	266,568	—	24,721	—	—
7½	172,842	253,177	—	80,335	—	Scarp of 1841
7	323,775	227,616	96,159	—	2,079,000	Through inlet and bar of 1841
6½	283,476	237,485	45,991	—	5,250,000	Counterscarp of 1841
6	293 345	216,661	76,684	—	6,160,000	—
5½	320,123	189,883	130,240	—	8,840,000	Scarp of 1901 { Deposited outside, 182,580 Scour inside 52,340
5	329,861	202,055	127,806	—	11,300,000	Gorge of 1901
4½	355,422	233,702	121 720	—	13,700,000	Counterscarp
4	322,581	402,893	80,312	—	5,555,000	—
3	323,775	283,607	40,168	—	10,000,000	—
2	206,924	234,919	—	27,995	2,000,000	—
1	158,236	186,231	—	27,995	—	—
0	121,937	139,978	—	18,041	—	On Sandy Hook Meridian
Av.	273,374	249,432	23,942		64,844,000	Deposited in 60 years ±

The difference of the mean sections gives an average reduction of 23,942 square feet, or about 900 cubic yards per lineal foot, which for the total distance of 46,200 feet would give 693,000 yards per year as compared with the nearly 1,100,000 as included in the bar reach and representing its annual increment.

The bar proper covers a length along the beach of about 3½ miles and extends seaward nearly the same distance, while the direction of its movement has changed since passing Rockaway Station from west to nearly southwest, and which, if continued, will pass through the Light on the Romer Shoal and bisect the Ambrose Channel. It is now

but 2½ miles distant from the 6-foot contour of the Jamaica Bar to the 14-foot depth at the end of the new channel. There are no points between reaching to 40 feet excepting a small basin ½ mile wide, having one sounding as great as 46 feet, and as the Jamaica Bar rolls up on the outer slope of the main ridge with its diminishing depth the rate of progress will be more rapid and the distribution of material more extensive.

The table above shows the maximum reduction of the cross-section of the waterway at Station 5½ (the present scarp) to have been 130,240 square feet, which is greater than the entire area of the waterway for the 3 knots covered by the initial section at Station O, so that there is not space on the bar for this deposit without spreading to the southward and flowing into the channel just as the spit at Sandy Hook is now changing its direction and moving to the westward as the ramparts of the sea encroach upon the gateways of the tide.

Rate of Approach.—Under these conditions the question naturally arises as to how soon this great increase in the volume of material may be expected to reach the bar, and it is one more readily answered than that of quantity, since a comparison of the authentic Coast Survey charts from 1841 furnish evidence that the progression of the easterly spit of Jamaica Bay has been 2⅞ miles in sixty years or at the annual average of 253 feet, that is, 1 mile in 20·86 years. If the British chart of 1776, made by Sauthier, be taken as reliable the rate has been about 7 miles in 125 years, or 295 feet per annum. One mile in eighteen years, nearly.

As a further check under somewhat similar conditions of exposure and activity the charts for Fire Island show a westerly drift of 11,600 feet in 52 years, or 224 feet a year. The Board of Engineers of 1897, in reporting on the conditions at Aransas Pass, Tex., on the Gulf of Mexico, stated that "for many years it moved in a southerly direction. . . . The annual rate of movement from 1868 to 1878 was about 260 feet."

These few instances will serve to show that a movement of about 260 feet a year is not abnormal, and may be ac-

cepted as safe, so that the 40-foot basin should be crossed in about ten years, after which the rate should be more rapid in mounting the scarp of the outer bar. As it will require about ten years to remove the original material in place, in the Ambrose channel, which is already reported to have filled from 3 to 7 feet, where work has been done, it will be seen that the problem assumes a serious aspect, and there would seem to be no question as to the futility of attempting to create, and especially to maintain, a channel by "dredging on a bar exposed to the full force of the Atlantic," which the board of 1884 could not recommend for its permanent improvement.

But this is not all, for while the marine forces of the Long Island littoral are so rapidly storming the left flank of the enceinte, those of the New Jersey coast are likewise attempting to turn the right and rear. It is, therefore, necessary to reconnoitre in this direction to ascertain the force of the enemy and his line of approach.

Growth of Sandy Hook.—The encroachments of this peninsula of sand extending northwardly across the entrance for a distance of five miles, has long been a subject of investigation and a cause of alarm lest it ultimately close this portal to the harbor. The U. S. Coast Survey Commission made a special report on this subject in 1857, in which it said:

"The disastrous result of the continued growth of Sandy Hook into the main ship channel, its progress having been for the last century at the rate of nearly 'a sixteenth of a mile in twelve years,' needs no exaggeration to give it importance. . . . If its encroachments in the same direction were continued beyond certain limits, the destruction of the harbor might ensue.

"Within twenty years (1835–55) the point has grown to the northward 220 yards. It is altogether probable that the future progress of commerce will render the deepening of the bar a vital question."

The half-century just closed has fully confirmed these predictions, and lends weight to the need of a more extended analysis of the rate and direction of the drift which is gradually throttling this mouth of the bay.

The rates of growth above cited give an average of 26 feet per annum for the century, and 33 feet for the score of years, but the variations in the progress of the spit will be more clearly exhibited by the subjoined tabular statement, compiled from numerous charts, some of which are of doubtful authenticity, and hence of little weight.

As the opening and closing of the mouth of the Shrewsbury River at the root of the Hook is a factor in the travel of drift, an effort has been made to determine the dates when open.

An old provincial map of New Jersey, published by Seller and Fisher in 1676, shows a small projection of $\frac{1}{10}$ of an inch in length on the site of Sandy Hook, connected with the mainland; but as there is no scale, it is valueless.

A map of New York and Perth Amboy harbors in 1733, drawn to scale and apparently made from surveys, is taken amongst the earliest reliable maps for this study. On this chart the Hook is but three miles long, which is apparently erroneous as compared with Lay's map of 1724. The depths of 19 fathoms in the narrows and $3\frac{1}{2}$ in the main ship and Gedney's channels are the same as those prior to the dredging, commenced under the project of 1884.

A glance at the rate-column shows some very eccentric features and impresses the need of systematic records at stated periods as a basis for definite conclusions. It would appear that, for the half-century from 1724 to 1776, the spit was in a condition of equilibrium (neglecting the survey of 1733). During Lord Howe's occupation a spit of sand nearly half a mile in length extended to the northwest, and the fast land soon followed it. Another cycle occurred between 1779 and 1848, a period of sixty-nine years, during which ·43 of a mile, or 2,288 feet, were reclaimed from the sea, giving an average progression of 33 feet per annum. Since 1848, whilst there has been fluctuation, there is no material advance upon the channel northwardly, but instead there has been a protrusion of a long spit of a half mile to the westward, forming the third cove on the inner face of the Hook.

MOVEMENTS OF SANDY HOOK AND CONDITION OF SHREWSBURY INLET.

Date—Year.	Lengths—Miles.	Feet.	Authority.	Inlet Closed or Open.	Average Rate Per Annum In Feet.	Remarks.
1724	4·00	21,120	Amos Lay	Closed	For 50 years to 1776 there seems to have been no advance	Scale 7m = 1″
1733	3·00*	15,840	Not stated	"		" 3⅓m = 1′
1769	3·96	20,909	Lt. Ratzer	"		" 6⅔ = 1
1776	4·00	21,120	(Hudson River)	"		" 4m = 1″
1778	4·40	23,232	"Lord Howe"	Open	1,056	" ¼ = 1″
1779	4·4	23,232	C. J. Sauthier	"	0	" 5 = 1″
1782	4 5	23,760	Lt. J. Hills	"	176	" $\frac{1}{10800}$
1819	4·53	23,918	Capt. LeConte	Closed	4	" "
1836	4·67	24,657	U. S. C. Survey	Opened in 1835	43	" "
1841	—	—	"	"	—	" "
1842	4·80	25.344	"	Closed	114	" "
1844	4·83	25,520	"	—	88	" "
1848	4·83	25,520	"	Open	0	" "
1850	4·80	25.344	"	Closed	— 88	" "
1851	4·78	25,388	"	Open	+ 44	" "
1855	4·77	25,335	"	Closed	— 13	" "
1857	5 00	26,400	"	" †	+ 530	† Permanently by railroad
1863	—	—	—	"	—	Severe storm cut away, making jetties and rip-rap necessary, 2,575 feet long.
1881	4·9	25,872	—	"	— 26	
1891	4·8	25,344	U. S. C. Survey	Closed	— 75	Scale $\frac{1}{10800}$

* Distance uncertain. † Six feet deep.

The revetment of the head of the Hook after the severe storm of 1863 checked the erosion to some extent.

In 1881 the nucleus of the westward movement was shown to have commenced. Taking the depth at 45 feet with slopes of 1 on 12, this deposit to date would represent approximately 10,000,000 cubic yards, or about a half-million a year, which has been arrested under the lee of the Hook, notwithstanding the inner littoral current which prevails for eleven hours out of the twelve. This does not represent, by any means, the additional amount of sediment carried into the bay in suspension and deposited in its channels and on its bars. The annual dredging required to maintain the full dimensions of Gedney's Channel, especially on the south

side of the cut, indicates the presence and source of this material.

This may be checked by the larger deposit made on the Hook proper between 1776 and 1857, when it advanced nearly a mile in length and expanded to a mean width of a mile. The uncertain element in this computation is the mean depth of the bed, but as there is always a deep water, reaction basin at the head of such spurs reaching to between 50 and 60 feet, it is safe to assume the depth of the fill at 15 yards. With these dimensions the yearly deposit has been 581,000 cubic yards on the fast land of the Hook, thus confirming within reasonable limits the probable annual deposit in this vicinity to be in round numbers 500,000 cubic yards. The northern mile of the Hook contains about 46,500,000 yards in place.

Unfortunately, the data contained in the above table furnish an uncertain basis from which to determine the age of Sandy Hook, but between the surveys of 1776 and 1857, a period of eighty-one years, it apparently advanced 1 mile, or at the rate of about 65 feet per annum. To cover the entire 5 miles, at this rate, would require about four centuries, leading back to the date of the discovery of America. It is highly probable that the rate was much less at an earlier date, when the coast to the southward was indented with numerous inlets which have nearly all been closed by the northward littoral drift and converted into fresh-water lakes. The only important openings to-day are those of Shark River and Manasquan, until Barnegat is reached, where the drift is to the southward.

From the foregoing statements it would appear that both flanks of the entrance are menaced by large deposits of sand in place, whilst the flood tide is augmenting this volume by material carried in suspension, thus hastening the deterioration of this entrance by these encroaching banks.

THE GREYTOWN HARBOR.

That this is no idle fancy will appear from a brief consideration of the physical conditions at the mouth of the San Juan del Norte, at Greytown, Nicaragua, upon which

so much stress has been laid in recent years. Here the trade-wind, rather than the tide, is the predominating element, to drive the waves to the westward and extend the hook in that direction, so that the excellent roadstead which existed in 1832 was completely sealed in 1865, during which period of thirty-two years the spit had advanced over a mile and a half, moving at an average rate of 291 feet, each year.

A careful computation from comparative cross-sections of this cordon of sand, covering a period of some forty years, made by the writer on the spot in December, 1897, gave the annual deposit as 582,000 cubic yards during the latter part of the movement.

By a comparison of the survey of Commander Lull, of 1872, with that of Captain West, of 1865, covering a little more than seven years, after the lagoon had been formed, Prof. Henry Mitchell estimated the average yearly deposit on the sea slope of Punta Arenas to be 730,000 cubic yards. Here the coastal plain is characterized by five distinct lagoons—Ibo, Barco, Sucio, Shepherd's and Greytown—having their axes nearly parallel and from 3,000 to 3,750 feet apart, all to leeward of the salient and within 3 miles of the coast, thus demonstrating the persistence of the forces and their cyclic results. The short pier of 1,000 feet, built by the Maritime Canal Company, arrested this drift and caused a general advance of the shore line to windward for a distance of more than a mile. It also opened and maintained a channel into the lagoon until the groin filled up.

This typical instance is cited to illustrate the gravity of the encroachments upon the New York bar where the aggregate deposits are more than twice as great, being concentrated from both the Long Island and New Jersey coasts, as from a funnel, upon the bar stretching from Coney Island to Sandy Hook.

Land Titles.—Aside from the physical, engineering or commercial importance of this question there is the legal one of proprietorship. Stakes, pins or landmarks driven into these traveling beaches do not hold them down and the inaccuracies of the early colonial surveys and descriptions are so vague as to lead to great confusion. In a

Supreme Court decision rendered in July last in favor of the town of Hempstead, Long Island, the defendant, based upon surveys several centuries old, the Court ruled "That old maps of the beach on Long Island are but slight evidence of the condition of the beach or the location of the inlets at a period fifty years earlier, even though correct at the time made. It is a fair presumption that the constant shifting in the various inlets of Rockaway Beach on Long Island, shown to be going on at the present time, was going on in 1725." From this it appears that such a description as is contained in the deed of "A beach lying on the south side of the Island at a place called Rockaway," is not such as would convey title to a definite tract of land, subject to the action of such physical forces.

For the purpose of preserving to the rightful owner the full possession of his property, therefore, it becomes of importance to establish well-defined reference marks and to ascertain by frequent and systematic examinations the character and amount of the changes which are taking place as a basis for the best method of reclamation and protection to riparian owners with correlative aid to commerce and marine industries.

The Remedy.—In view of the situation the preventive measures seem to be self-evident, yet thus far no permanent regulating works are contemplated which look to the modification of the tidal forces, either to diminish the rate of encroachments from the flood-driven sand bars or to augment or localize the energy of the ebb scour, so that it is risking nothing to say that the Board of 1884 was correct in its judgment as to the inexpediency of attempting to meet the demands of commerce by dredging. If it were true then, it is more so now, and yet it is quite possible so to control the ebb currents by a permanent training wall as to cause them to cut out and maintain by their own energy an ample channel across this bar. Such a structure would not obstruct nor close any of the existing channels, but would protect the Ambrose Channel from drift and would cost only about one-half the amount estimated for merely the preliminary dredging of the proposed channel. This should

be supplemented by auxiliary works to impound the traveling sands in natural depositories, where they will become valuable instead of injurious, and prevent the ultimate formation of a new beach in front of Manhattan and Coney Island, which will ultimately be on a bay a mile or more from the sea.

The details as to plans, dimensions, mode of construction, materials and cost of these works, belonging more properly to the subject of the Engineering Section, are consequently omitted from this paper, which is respectfully submitted for discussion, though with a consciousness of the deficiency and unreliability of the earlier data.

CLOSE OF THE ST. LOUIS FAIR.

The Exposition at St. Louis, which was opened to the public with an attendance for the first day of about 180,000, was brought to a close on December 1st, with a record of over 200,000 admissions. The closing day was marked by ceremonies expressive of the debt which the Exposition owes to the executive ability and enthusiasm of its president, the final addresses being delivered in the Plaza St. Louis, and at the foot of the Louisiana Purchase Monument, where seven months ago the Exposition was formally declared to be opened. The Exposition buildings were closed at four o'clock in the afternoon, and at midnight the splendid illuminations of Festival Hall and the Cascades slowly faded out for the last time, leaving this, the largest, most ambitious of the great international expositions, a matter of history.

Interest naturally centers at this time in the finances of this great undertaking, and according to a statement of the secretary of the project, since its inception, has cost about $22,000,000 to the Exposition Company, while the several States and Territories have expended a total of $9,000,000. There were 18,500,000 admissions, and the receipts reached a total of about $10,000,000, which is made up of admissions and concession royalties. It was announced that when a few current accounts have been paid, most of the $1,000,000 in hand will have been consumed, leaving only a small amount for the stockholders. From the amount of royalties collected, it is estimated that the various concessionaires must have taken in at least $10,000,000. The entire cost of the whole fair, including the various concessions, is estimated at about $50,000,000. With the bringing to a close of one more of these colossal expositions, the question will be asked again as to whether they pay. From the figures given above it is evident that financially they do not; but everyone who has visited this fair and taken note of the character and behavior of the multitudes that streamed through the various Exposition palaces, will surely give it as his impartial conclusion that as a great educative force, whose influence is much wider than can be measured in turnstile statistics, the last of the world's fairs must, in a broad sense, have been a profitable undertaking.—*Scientific American.*

Mining and Metallurgical Section.

Stated Meeting, held Thursday, December 22, 1904.

Fundamental Principles Involved in Blast-Furnace Practice.

By Edward A. Uehling, M.E., New York.
Consulting Engineer and Member of the Institute.

To produce with the greatest possible regularity and fuel economy, the maximum per cent. of the quality of iron desired, and the maximum output of which the design of the furnace and its mechanical equipment will permit, none of the recognized essentials must be overlooked, and many things observed and attended to, that have not received the consideration which their importance merits.

RAW MATERIAL.

The Ore should be of uniform quality, or a uniform mixture of ores of dissimilar qualities, chemically adapted, to yield collectively the iron desired, and to produce with the flux available that quantity and composition of slag best adapted to fulfil its proper functions in the process of smelting. Neither a very lean ore, or ore mixture, nor yet ores that are exceedingly rich in iron, are conducive to obtaining the best results, but a regular mixture of low grade ores will yield better results than an irregular mixture of much higher average grade, certainly as to quality and generally also as to quantity of output. In regard to a few of the chemical elements the ore must be, and always is, selected and mixed to produce the desired iron; but in regard to the physical condition there is at best but a limited choice and frequently none whatever. It may be laid down as an axiom, that the more refractory an ore is the finer it should be physically to become readily reduced. In the storeroom of nature we find, however, that the more refractory ores occur generally in compact masses, while those easily reducible

are most frequently found in a more or less finely comminuted state.

The logical corollary to the above axiom, viz., that the finer the comminution of an ore the greater its reducibility, and hence the more readily it can be smelted, while theoretically correct, does not hold good in the blast furnace, and especially not in the modern blast furnace. Two reasons why this should be so present themselves very readily; first, the finer the ore the greater must be the resistance offered to the ascending gases, and, second, the greater must also be the quantity of ore dust carried over into the gas flues. These difficulties give rise to others which with certain ores have frequently proven serious.

In smelting very fine ores the increased blast pressure was the objection that made itself felt first, and in the measure as this was being overcome by stronger blowing engines, the loss in flue dust was increased. No serious difficulties were encountered, however, until after the advent of the ores from the Mesabi range. These ores, while unsurpassed in chemical composition, ease of reduction, and cheapness of getting, possess physical properties which illy adapt them for conversion into pig iron in the monstrous blast furnaces in which they are being smelted. In the majority of the deposits the very fine ore preponderates, in some cases as high as 20 per cent. will pass through an 80-mesh sieve. Much of this very fine ore is carried over with the gases. The average loss of Mesabi ore in flue dust is between 3 and 5 per cent., and greater loss is not uncommon.

PREPARATION OF ORES.

Crushing.—Although much advance has been made in the past decade in the way of preparing the harder varieties of ore by crushing them, generally at the mines, which is the proper place, instead of depending on a few men in the stock-house to break up the largest lumps with sledge hammers; yet, little or no attention has been given to the actual requirements. All hard ores are crushed to a given size, irrespective of their reducibility. Hematite ores generally go into the furnace in a finer state of comminution than

magnetites, when because of their great reducibility the reverse should be the case. It is the author's opinion that all hard ores could bear much finer crushing than is at present customary, and that this would be conducive to fuel economy particularly with the magnetites. The latter could be crushed with advantage so as to pass through a 2-inch round-holed screen, and even smaller.

Sizing.—The importance of sizing or separating ores with regard to their relative coarseness or fineness has as yet received but little attention in American blast-furnace practice. I dare say the majority of furnace managers have not given this phase of the subject the thought and careful study it deserves.

Every furnace man objects to either very fine or very coarse ores, and all would, no doubt, prefer a uniform and relatively coarse ore, but since it is quite the exception that uniformly coarse ores can be supplied, they must be taken as they come, and the general practice is to charge the coarse and fine ores indiscriminately as they happen to be at hand, or at best attempt to mix them as much as possible. The former method is bound to produce more or less serious disturbance in the working of the furnace; not only because of the physical irregularity, but also because the fines of a given ore may vary very considerably in composition from the coarser portions. The uniform mixing of the coarse and fine ores, though much better chemically, at least, is, nevertheless, far from being the best method of charging.

The worst possible ore mixture, from a physical point of view, is that in which the coarse and fine are so proportioned and so thoroughly mixed that the latter fills all the interstices between the lumps of the former. A layer of such a mixture is less penetrable, offers greater resistance to the ascending gases, hence requires a higher blast pressure and is apt to produce more flue dust, and is therefore less desirable than if it consisted of fine ore alone. This is true to a greater or lesser extent of all mixtures of irregular sizes, and the greater the difference between the coarse and the fine, the worse. To be right, ores should be sepa-

rated into three, or preferably into four sizes, viz.: coarse, medium, fine, and dust. All ore passing over, say, 1½-inch mesh screen to be classed as coarse; through 1½-inch and over ½-inch to be classed as medium; through ½-inch and over $\frac{1}{20}$-inch mesh to be classed as fine, and all that passes through $\frac{1}{20}$-inch mesh to be classed as dust. The latter should either be briquetted or agglutinated in some satisfactory manner or else smelted in a furnace by itself, designed and equipped for the purpose, preferably in a low, wide furnace, blown with a mild blast through tuyeres of variable penetration, or perhaps electrically. The coarse, medium and fine ores could be smelted together in the same furnace with a strong blast. To do so to the best advantage they should be charged in separate strata. The above scheme, *i. e.*, to first separate the ore into several sizes and then fill them separately, will, no doubt, be objected to as impracticable, as an expensive and useless complication, or at best a refinement of doubtful utility. Whether such objections are all, or only partly, or not at all true, depends on our viewpoint. If we should attempt it with the present equipments, even the most modern, it would probably be impracticable; if we feel that we have reached the acme of perfection in blast-furnace practice, it must seem a useless complication, and if the present output is qualitatively as well as quantitatively fully satisfactory, the sizing of the ores would certainly be of doubtful utility. If, however, we wish to combine uniform quality with maximum output and greatest fuel economy, we must seek to eliminate all disturbing factors, and the physical irregularity of the raw material certainly is one of them.

Roasting the ores is resorted to generally only for the purpose of eliminating such deleterious constituents from the ore as can be driven off by heat. The process is always carried on in an oxidizing atmosphere. In this country the roasting of ores is rarely resorted to, except for the purpose of eliminating sulphur. All magnetic ores are improved by roasting, and the question whether it would pay or not to do so depends entirely on local conditions; first, on the cost of coke or other furnace fuel, and, second, on the market value

of electric current. The same is true with other varieties of ores; for example, the hard red ores of the Birmingham district, which could be greatly improved by roasting. Time and space do not permit going further into this subject at this time.

Briquetting, Agglutinizing, Cindering, Electric and Chemical Treatment—all these relate to putting ore dust into some form that will overcome its objectionable qualities. Much time, ingenuity and money have been expended in this direction, resulting mostly in failure or at best in indifferent success. This, however, does not imply that the problem cannot be solved, or even that it may not have been solved already by some method awaiting practical demonstration and commercial development. Much could be said about promising methods, if time permitted.

As stated above, theoretically, the finer the ore, the more economically it should be smelted. To the practical objections already mentioned which manifest themselves against the use of very fine ores, viz., heavy blast pressures and reduced yield, etc., should be added the difficulty encountered in properly distributing the fine ores over the coke charge. The latter problem fully solved, the author is of the opinion that the very fine ores could be smelted to best advantage by themselves in a specially designed blast furnace. Smelting in an electrical furnace possesses possibilities of success which depend chiefly on the cost of power, and with the proper utilization of the blast-furnace gas its practicability as an adjunct to the blast furnace becomes very much less doubtful, and may prove profitable under certain local conditions.

Flux.—Under the general term of flux, we understand that addition to the material smelted, which will chemically combine with the gang and other impurities of both ore and fuel and produce a liquid slag. It so happens that with very few exceptions the acid elements contained in the gang largely predominate. For this reason, the flux must nearly always be basic, and because of its abundance and cheapness, limestone is almost invariably used. Should, however, the basic element in the ores predominate, an acid

flux would have to be added, and quartz rock or highly silicious iron ore take the place of limestone.

Preparation of Flux.—What has been said of the preparation of ores holds good in a general way also for the preparation of the flux. It should be well broken, and as much as possible of uniform size; dust should be entirely avoided. Theoretically, it would be of considerable advantage to calcine the limestone or dolomite before filling into the furnace. There are, however, practical difficulties due to the fact that unless the stone is very hard burned, it readily becomes air-slaked, and is then worthless, since it is too largely carried over by the blast. Attempts that have been made to drive off the carbonic acid before filling into the furnace have generally failed on that account.

Slag.—The function of the flux, as we have seen, is to fuse with earthly impurities of the ores and fuel and melt into a liquid slag. The function of the slag is two-fold—physical and chemical. Physically it acts first as a filter, purifying the globules of reduced iron as they pass through, and, second, as a blanket protecting the metal against possible oxidation by the blast. Chemically its most important functions are to absorb and carry off sulphur, and to assist in regulating the silicon content in the iron.

Magnesia is a stronger flux than lime in ratio of their respective atomic weights, and with an ore mixture comparatively free from sulphur smelted with a low sulphur fuel, dolomite is proportionately more efficient than carbonate of lime; but since sulphur exists in the slag only in combination with calcium, the latter element must predominate where considerable quantities of sulphur are to be removed.

The proper composition of the slag is of greatest importance, and in selecting ores, and also the fuel, due consideration should be given to the composition of the gang and ash respectively. Alumina should be kept as low as possible. Although this element does not materially reduce the fusibility, it does largely reduce the fluidity of the slag, and fluidity is of the most vital importance in a blast-furnace slag. So far as the author's experience goes, the lower the

alumina can be kept the better; and if a slag results from the regular mixture containing over 15 per cent. of alumina, silicon material should be added to the burden. A slag to be most efficient should melt like ice, and not like taffy; that is to say, it should retain a solid form until it melts, and as soon as melted it should be quite liquid, instead of gradually passing from the solid to the liquid state. The latter property causes sticking and hanging, and on account of the sluggishness of such a slag, it cannot fulfil its functions properly. It has a tendency to retain the finer globules of iron, thus causing material loss.

Generally the ores contain ample earthy impurities so that with the addition of flux necessary to form a desirable slag, the proper quantity is also produced. In many instances it has proved to be good practice to add silicious material for the purpose of improving the quality of the slag as well as of increasing the quantity.

Fuel.—The fuel for the blast furnace may be raw coal, charcoal, anthracite, or coke. The first of these has entirely ceased to be a factor in the production of pig iron in this country. The percentage of charcoal used is becoming less and less as timber becomes scarcer and dearer. The same holds true for anthracite coal, because of its limited supply, and although still used in considerable quantities it is bound to be practically replaced by coke in the not distant future. Coke, besides its practically unlimited supply, possesses all the essential qualities of a superior blast-furnace fuel.

The fuel performs two functions in the blast furnace—physical and chemical. The physical function of the fuel consists in preserving a comparatively open stratification in the descending column of stock in the furnace, thereby permitting an easy upward flow of the ascending gases. To fulfil this function properly the fuel should be coarse and rough, and as uniform as possible in size. Very large lumps are as undesirable as fines. It should be of sufficient strength to reach the tuyeres with the least loss by abrasion. Fuel dust, or breeze, should never be charged into a blast furnace; the most of it is directly blown over with the gas, and what little is retained in the furnace is apt to do more harm than good.

The chemical functions of a blast furnace fuel are twofold. (1) To generate by semi-combustion with the oxygen of the blast, all the heat necessary for the process of smelting, and (2) to produce the reducing gas necessary to convert the ore to the metallic state. It should possess the greatest possible cell development consistent with the required physical strength, so as to offer the maximum surface to the oxygen of the blast, and yet possess such chemical stability that it is but slightly affected by the oxidizing action of the CO_2 in the upper zones of the furnace. To possess these properties the first requisite is that the coke is well burned and made from coal which will produce the proper cell structure and necessary strength.

The most objectionable element contained in coke is sulphur. Phosphorus is of importance only when special irons are being manufactured. The composition of the ash is of as much importance as the quantity. The alumina should be as low and the silicon as high as possible. This holds true especially where foundry iron is smelted. Iron is a valuable constituent, and is often contained in sufficient quantity to add appreciably to the yield of the ore. The author is of the belief that most of the silicon in the iron produced comes from the ash of the coke; and if the ash, therefore, is of the proper composition it may add materially to the ease of producing high silicon iron.

Air.—The largest, the cheapest, and the most neglected constituent of the raw materials involved in the process of smelting is the air which furnishes the oxygen required to burn the fuel and produce the heat and chemical reactions.

Strictly speaking, the blast is furnished to every furnace variable in quantity, irregular in temperature, and, worst of all, variably contaminated by moisture, and because of these, as much as other irregularities, also at variable pressures.

Regularity of Blast.—First regular quantity. It is probably quite within the memory of most of the older furnace men, if not within their own experience, that it was the general practice to regulate the blast by pressure. In England, where they still generally blow several furnaces (as many as six or more) off the same blast main, this practice

of necessity prevails. In this country blowing by volume is the rule. The blowing engines are ordered to be run steadily at the required revolutions; but variable steam pressure is a disturbing factor, variable blast pressure is another. Then again constant revolutions, *i. e.*, constant volume by engine measurement does not insure a constant quantity of blast delivered into the furnace. Innumerable, avoidable and unavoidable leaks, between piston and tuyeres, engine-room temperature, and the barometric pressure of the atmosphere, affect the quantity delivered. The latter alone may affect the quantity delivered from 6 to 10 per cent., and loss through leakage from 10 to 15 per cent. and more is not uncommon.

The author believes himself to have been among the first to blow a furnace by constant volume. The change from pressure to volume blowing at once brought a noticeable improvement in the regularity of the output, but the number of charges taken by the furnace did not agree as closely as they should with the regular quantity of wind supposed to be delivered by the blowing engines. Revolution counters were attached to the engines, and the fact was at once revealed that the revolutions marked had not been regularly blown. Getting the engineers interested resulted in a friendly rivalry to blow the exact number of revolutions. For longer or shorter intervals the fuel charges would agree with the revolutions, then again there would be puzzling discrepancies that could not be explained by irregularities in the working of the furnace. Barometer and thermometer observations finally practically cleared away all otherwise unaccountable discrepancies, except that the calculation showed the quantity of air delivered by the blowing engine to be far in excess of that required to burn the fuel consumed. The numerous small leaks, which had not been considered of much importance prior to accurate determination of wind and fuel relation, were stopped, and a gain of 5 tons per day was the result.

These few digressive remarks are recited here merely to show the importance of small things. There is so much in the phenomena of smelting in a blast-furnace which cannot

be directly observed, that it behooves every furnace manager who wishes to keep intelligent control over his charge to pay attention to all the influencing factors. The barometer and the wet and dry bulb thermometer have received practically no attention. Revolution-counters are not as generally adopted as they should be. Autographic recording instruments should be used wherever available. The fact that the cost of air does not directly enter into the cost sheet is no reason why it should not receive proper attention.

Regular Temperature.—Neilson's invention of the hot-blast stove was, no doubt, the greatest single step taken in advance in the process of smelting iron in the blast furnace. Every 100° of heat added to the temperature of the blast is equivalent to 3 per cent. of the carbon burned at the tuyeres.

To what degree it is practical and economical to carry the heat of the blast is still an undetermined question. Practical furnace men differ much in their opinion. Sir Lothian Bell came to the conclusion, derived from his famous investigation of the chemical phenomena of the blast furnace, that not much could be gained after reaching 1,000°; nevertheless, they are to-day carrying at his own furnaces as regularly as possible from 1,400° to 1,500° at the Clarence Works, Middlesbrough, England. In Germany 1,500° to 1,600° of blast temperature are not uncommon. In this country the average blast temperature does probably not very much exceed 1,000°. Some furnace managers would like to carry higher temperatures if they could get them; others contend that high blast temperatures invariably lead to trouble. Theoretically, the limit of blast temperature is not reached until the fuel displaced by the heat of the blast has reduced the quantity to such an extent that the CO formed is insufficient in quantity to reduce the ores carried. The blast furnace cannot be successfully worked on heat alone. A sufficient quantity of reducing agent must be supplied as well, and there must be enough solid fuel to fulfil its physical function. While there is, therefore, ample room for difference of opinion as to what is the most eco-

nomical temperature, there exists no such difference of opinion as to the desirability of a controllable regular temperature.

The introduction of the regenerative hot-blast stove was a great improvement over the iron-pipe stove in so far as enabling higher temperatures to be obtained; at the same time, it brought with it the very detrimental factor of variability of temperature. The loss of temperature in an hour's blowing, which is the almost universally adopted period, is rarely less than 200° and not infrequently reaches 300° and more. Since 100° blast temperature are equal to 3 per cent. of the fuel burned at the tuyeres, we see that these variations amount to from 6 to 10 per cent. of fuel in the hearth. That this variable factor must necessarily produce detrimental variations in the vital part of the furnace is evident. How this variation can best be avoided or overcome the author has attempted to show in an article published in the *Iron Age*, May 19th last.

With thoroughly purified gases the hot-blast stoves can readily be so constructed that they will yield a blast of very high and practically uniform temperature, which can then be readily tempered down to any degree necessary or desirable. So long, however, as iron masters will persist in using dirty gases, there is little chance of improving the hot-blast stove. The only thing to do is to make them bigger and build more of them. Why furnace proprietors should persist on these illogical and costly lines is difficult to understand. The money put into new and enlarged hot-blast stoves would nearly, if not quite, pay for an installation of gas-washing plant, which would produce much more economical and satisfactory results; as the author has shown in the paper referred to above, that the blast can be readily kept at a uniform temperature by the introduction of cold blast. To do this, however, it is absolutely necessary to know the blast temperature, and it is strange to say that with a few laudable exceptions, blast-furnace managers east of the Allegheny Mountains have not availed themselves of the proper means to do this.

To have control of the heat, it is not sufficient to test the

temperature once an hour, but you must be able to see what the temperature is at any moment, and what is even more important is to have an instrument which is absolutely beyond the control of the man responsible for the temperature. An autographic record is of the greatest value. Without a positive knowledge of the temperature carried at all times, intelligent heat regulation is impossible and perfect control out of the question.

Composition of Blast.—There are few, if any, furnace managers that are not aware of the fact that humidity is an important element in the blast. Very few, however, have taken the pains and the trouble to determine what this factor amounts to quantitatively. During the period referred to above, the author made hygrometric determinations and was surprised to find that the quantity of water carried into the furnace by the blast during the humid summer months amounted to tons of water in twenty-four hours. It is not uncommon for the air to contain 8 grains of moisture per cubic foot. At this degree of humidity a blast furnace taking 35,000 cubic feet of air a minute will, therefore, receive

$$35{,}000 \times 8 \div 7{,}000 = 40 \text{ pounds of water vapor per minute,}$$

or 2,400 pounds per hour, or over 28 net tons in twenty-four hours. Since that time (1886) the author has persistently advocated the economical importance of removing this moisture from the blast, and the process of refrigeration as the best method for removing it.

Knowing the amount of moisture going into the furnace with the blast, it is easy to figure the fuel required to neutralize its chilling effect. Making this calculation we find that one pound of moisture requires in round numbers 1·3 pounds of carbon to be burned at the tuyeres to replace the heat absorbed by the decomposition of the water vapor. This, in itself, amounts to a very considerable quantity of fuel during the summer months, yet it is less than 25 per cent. of the actual fuel saved, as demonstrated at the Isabella Furnaces by Mr. Gayley's desiccating plant.

The strictest attention is paid by every furnace manager

to guard against water getting into the furnace through leaky tuyeres or cooling plates, yet absolutely no regard is given to the contamination of the blast by avoidable moisture. Innumerable steam leaks are often allowed to exist in the engine-room, nearly all of the steam from which is carried into the furnace without any idea of the fuel necessary to overcome this extra moisture. So long as these leaks do not become positively annoying to the engineer, they are rarely attended to. One instance in the writer's experience may be permissible to illustrate. At the plant in mind the blowing engines and pumps were in charge of the master mechanic of the works, over which the furnace manager had no authority. Repeated requests to repair the leaky joints were ignored. Hygrometric tests of the blast showed that it contained between 5 to 7 grains of moisture per cubic foot above the outside atmosphere. Calculations based on this moisture content laid before the general manager brought the necessary pressure upon the master mechanic. The steam pipes were overhauled. The effect was an immediate reduction in the fuel consumption of 150 to 200 pounds per ton of iron. There is no doubt in the author's mind that similar fuel economies might be obtained at many of the existing plants.

In the author's estimation desiccation of the blast is a step in advance, second in importance only to the hot blast, and that it will be as generally and perhaps even more promptly adopted.

Chemical Reactions.—Practical furnace men are, as a rule, very much in the dark as to the chemical reactions which take place inside of the blast furnace. Accurate data, both as to the temperatures existing and changes which take place in the various zones of the modern blast furnace, are entirely wanting. Such an investigation as was carried out by Sir Lothian Bell nearly forty years ago is very badly needed to throw light on what actually takes place in a blast furnace under the so materially changed conditions and methods of modern practice.

Every blast-furnace manager knows, of course, the nature and composition of the raw material charge at the top, and

the physical condition and chemical composition of product tapped out at the bottom, and can and should know the composition of the escaping gases. And all this indicates to him more or less clearly what is actually going on inside of the furnace. But in reality all he knows with certainty is the beginning and the end. We know that all the carbon that reaches the tuyeres is burned to CO, and that this reaction is the principal source of heat by which the process of smelting is carried on, and that the CO is the all-important reducing agent.

From the composition and temperature of the escaping gases we can make inference as to the relative efficiency of the furnace at the time. From the appearance and chemical composition of slag and iron we can tell whether the furnace is in good or bad working condition, but of the actual chemical reactions taking place in the interior of the furnace, either as to their sequence or relative importance, we know practically nothing.

Carbon Impregnation is one of the important phenomena about which we are still very much in the dark. It had been observed before, but was first prominently brought before the iron metallurgists through the researches of Sir Lothian Bell, that sesqui oxide of iron (Fe_2O_3) possessed the property of splitting up CO into $C + CO_2$ at temperatures existing in the upper region of a blast furnace. This phenomenon has recently been the subject of scientific investigation and is very ably discussed in *Stahl und Eisen*, No. 21, 1904, by Dr. Aloys Weiskopf.

All hematite ores possess this quality to a greater or lesser degree and some of these from the Mesabi range are most remarkable for their capacity to become impregnated with carbon.

Experiments conducted by Mr. O. O. Landig* showed that the ore of some of the deposits became impregnated to such an extent that their volume was very considerably increased. This being so, it is more than probable that

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* *Transactions of American Institute Mining Engineers*, Vol. XXVI. "Action of Blast Furnace Gas on Various Iron Ores."

most of the difficulties experienced in smelting the Mesabi ore are due to this quality of excessive carbon impregnation.

Hanging of the Stock in the upper part of the furnace is, no doubt, entirely due to this phenomena, for it necessarily follows that the swelling of the ore must increase the resistance to the gas currents and must also increase the friction against the inwall of the furnace. Now if we consider that even under the most favorable conditions, by far the greater part of the column of stock is supported by the normal friction against the inwall, and the further fact that 1 pound of unbalanced gas pressure will sustain approximately 1 foot in height of the column of stock, it is not difficult to understand how the downward movement of the solid material may be arrested without involving any other factor than excessive carbon impregnation.

A portion of the stock column having once come to rest, it is bound to remain at rest until the cause of arrest is removed. This necessarily follows from the fact that friction of rest is greater than friction of motion, so that if there is sufficient friction and pressure developed to cause a moving body to come to rest, there is always more than necessary to hold it stationary. Meanwhile, the consumption of fuel continues at the tuyeres in accordance with the volume of oxygen forced in by the blast. The iron sponge is carburized and melted, the dross of both ore and fuel combines with the flux and is fused into a liquid slag which descends with the iron into the hearth, where they take up very little space compared with their original bulk, and from which they are tapped off from time to time. As this process of smelting goes on, that portion of the column of solid material which is free to move in the furnace shaft above continues to descend. This causes a break between the arrested and moving part of the stock column. A cavity is soon formed which continues to increase in dimension in proportion as the moving column is smelted and consumed. The shorter this column gets, the less is the resistance it offers to the ascending gases, hence, with a given blast pressure, the pressure in the cavity must also increase, thus giving the stationary column still greater support.

Slipping.—On the other hand, it is evident that since no cold stock enters the furnace during the period of hanging, its contents must become hotter and hotter; also that the increased temperature will accelerate chemical reaction. Reduction progresses more rapidly; the carbon deposited at the lower temperature is consumed by the oxygen, liberated from the ore which it had impregnated, or by reducing CO_2 to CO, probably both. As this process proceeds, the stationary column necessarily shrinks, gradually loses its hold on the wall, and finally breaks away. This phenomenon is called a slip or slipping.

There are two distinct varieties of this phenomenon, the one due to causes just discussed known as top slips, always occurring in the upper half of the stock column; and the other, called bottom slips, to which I shall recur later, due to causes entirely different and always occurring in the lower part of the furnace, generally within the limits of the hearth and bosh.

To have a furnace slipping is always unpleasant. It is frequently serious and on several occasions resulted very disastrously.*

Prior to the introduction of the Mesabi ores, top slips were of very rare occurrence, and when they did occur were of a comparatively mild form, but no sooner had these ores become an appreciable part of the ore mixture than these phenomena of slipping became more and more frequent and very often manifested themselves with such force that "explosion" seemed to be a more appropriate term than "slip," and hence the phenomena is generally referred to as "Mesabi ore explosions."

When we consider that the dislocation of the charging hopper and top plates was an every-day occurrence and that on several occasions the whole charging apparatus, weighing many tons, was blown clean off the furnace and large

* It will be remembered that Captain Jones lost his life by being enveloped in white hot coke, slag and molten iron, bursting forth from one of the Edgar Thompson Furnaces in consequence of a bottom slip, and that Ed. Reisse was burned to death by the hot stock thrown from a furnace in his charge at New Castle, Pa., due to a top slip.

quantities of stock were scattered broadcast, it appears quite natural that the explosion hypotheses should have seemed necessary to explain the effect produced.

On the other hand, a little calculation will show that the force necessary to throw a bell and hopper out of a furnace is not so great as would appear from the mere statement of the fact that they weigh many tons. A gas pressure of 1 pound per square inch, when applied to a circular area 12 feet in diameter, exerts a lifting force of considerably over 8 net tons, and on an area of 14 feet in diameter of fully 11 net tons. This is quite sufficient to lift the average bell and hopper out of place.

What pressure of gas is produced by a top slip depends on the size and the shape of the cavity developed during hanging, as well as the temperature and pressure of the gas it contains, the weight of the suspended column, and the manner in which it drops. There being no means of making direct observation, we can only reason from effect to cause, and the severity of the former has given rise to the assumption that the latter must be some form of explosion. Whether this view is tenable or not depends entirely on how broadly we define the term "explosion." In reality it matters little by what name we call it so long as it does not lead us to a wrong conception of the phenomena of which we are endeavoring to get a clear idea and find an adequate and rational explanation.

Let us suppose that the upper 10 feet of the stock in a modern blast furnace become arrested, *i. e.*, hang. The furnace working normally below, a cavity will at once begin to form, and will increase as fast as the descending column is consumed at the lower end by the process of combustion and smelting. As the descending column shortens, the resistance to the ascending gases through it becomes less, and since the condition of the hanging column is but slowly changing, the gas pressure in the cavity steadily increases. The same is necessarily true of the temperature since the gas passes through material which is getting hotter and hotter as it approaches the zone of fusion. While the increased pressure tends to support the hanging column

indefinitely, the increased temperature stimulates chemical action referred to above, and the deposited carbon is gradually consumed. This burning out of the impregnated carbon causes shrinkage of the suspended material and finally results in its dropping or slipping into the cavity below.

It does not require any very considerable stretch of the imagination to suppose that the hanging column, which we assumed to be 10 feet high, to drop like a practically solid plunger into a cavity below 10 or 15 feet deep. This cavity being filled with highly heated gas already under considerable pressure, the necessary immediate effect would most likely be as follows: The hot gas below will be compressed proportional to the weight and momentum of the descending mass, and the partial vacuum formed above will be filled by cooler gas rushing back into the furnace from the gas mains, mingled with more or less atmospheric air drawn in through the leaky bell and poorly fitted explosion doors. Immediately the pressure of the compressed gas is sufficient to overcome the resistance offered by the plunging stock column; it breaks through with force and instantly mixes with the cooler gases above, raising them suddenly to a high temperature, which later may be very materially augmented by the instantaneous combustion of the oxygen present, resulting in a pressure sufficiently sudden and high to produce effects akin to real explosions. The author is not aware that the pressures of these so-called "explosions" have ever been measured, but it is doubtful whether they often exceed 10 or ever reach 15 pounds per square inch. The lesser of these pressures would be quite sufficient to throw any bell and hopper not securely fastened down, clean out of the furnace.

It must not be supposed that top slips always take place in the extreme manner of our hypothetical case just described. Generally the hanging stock drops into the cavity below less suddenly, the phenomena lasting over many seconds and sometimes minutes; nevertheless, considerable quantities of fine ore and coke are thrown out with every slip, and not infrequently large quantities of the coarser material, especially coke, as well. The large furnaces, work-

ing principally on Mesabi ore, apparently work by slips only. It is the exception rather than the rule that twenty-four hours pass without appreciable slipping. The quantities of coke and ore that are frequently blown out through the explosion doors and scattered over the premises are appalling. There is one feature about these phenomena which, since their destructive effects have been overcome by structural improvements, makes them less objectionable than would at first appear. The real process of smelting is but very little, if at all, disturbed by them. If it were not for this fact, top slipping would have become intolerable long ago. As it is, large output and acceptable quality are still attainable.

In the light of our present knowledge, top hanging and slipping seems to be attributable to two causes: first, the inherent condition of the ore, and, second, over-exposure. The first can be mitigated by judicious selection and admixture of the ores and proper charging, and the second cause can be largely, if not altogether, avoided, by smelting these ores in furnaces better adapted to their requirements. The modern excessively high furnace is an absurdity when we consider reducibility and other properties, both physical and chemical, of the ores smelted in the majority of them.

Bottom Slipping.—Bottom slipping is a phenomenon quite different from top slipping, and it is due to entirely different causes. Bottom slipping occurs entirely within the zone of fusion and is chiefly caused by temperature variations due to direct variations in the blast temperature, the irregular moisture content, and to changes in the carbon content in the fuel. Irregularity in the composition of the slag aggravated by temperature changes is probably the most prolific cause of hanging and slipping in the lower part of the furnace. Excessively basic slags are more inclined to build up than acid slags. High alumina slags are especially bad. Bottom slips invariably spoil one or more casts of iron, and not infrequently block up the hearth and tuyeres to such an extent with a cold refractory conglomerate of partially reduced iron, slag, carbon dust, lime, and fine coke, that heroic means are required to get the furnace into proper shape

again. Not more than a generation ago these bottom slips very often proved fatal to the campaign, or at least required days of sledging and drilling, to get the blast properly into the furnace and the molten iron and slag away from it. The introduction of the oil blow-pipe proved itself of great assistance to the troubled furnace manager, and latterly the electric arc makes playwork out of the task of opening up frozen tuyeres and chilled iron and cinder notches, compared with the sledge and chisel of the olden days.

Scaffolding.—When the accumulations which give rise to bottom slipping cease to come off, *i. e.*, become chronic, we have scaffolding. There can be no doubt that all scaffolding starts in the zone of fusion, and is due to the causes that give rise to bottom slips. If that is true, what would prevent the latter, would make the former impossible. Whether these disturbances can ever be entirely overcome may be questioned, yet there is still so much room for improvement in furnace practice, *e. g.*, in the preparation of the ore and flux, the selection of the fuel, the manner of charging, uniform blowing, desiccation and regular heating of the blast, etc., that many of the troubles now of still too frequent occurrence may be almost if not entirely eliminated.

MECHANICAL CONDITIONS.

Distribution.—The proper distribution of the stock is one of the most important factors in the operation of the modern blast furnace, and this has been greatly emphasized since the introduction of the automatic charging apparatus. There are few conditions in connection with the designing and management of the modern blast furnace, that have given so much trouble and worry to the engineer as well as the furnace manager. While much has been done to overcome the inherent tendency of the skip-hoist to distribute the coarse and fine ore unequally, and much improvement has been made, the charging device that will distribute all the different kinds of material satisfactorily has not yet been invented, or, if invented, has yet to demonstrate its practicability and effectiveness.

The ideal charging apparatus, in addition to fulfilling

the paramount requirements of being strong, durable, and forming perfect gas-seal, should be under such control of the man in charge that the material charged, irrespective of its physical condition, can be distributed from the hopper evenly over the entire area of the furnace or practically in a ring against the outer wall, all in the center, or in intermediate circles, or, if need be, in a heap in any desired point of the compass. With such a charging apparatus many of the difficulties now encountered would be entirely avoided, and such irregularities in the settling of the stock which might still occur could be speedily remedied. To be able to use such a charging apparatus to its full possibility it should be supplemented by an automatic stock-level indicator.

Whether the above ideal will ever be reached, or even approximately realized in practice, may be questioned; but there can be no question as to the shortcomings of all existing apparatus. The bell and hopper which fulfils the first three requirements perfectly, falls far short as a distributor because of its narrow limitations and inflexibility, especially in connection with the automatic skip-hoist.

When filling is done by hand it is generally possible, by exercising proper care and judgment, to distribute the stock in a manner most conducive to good results. All the ores should be separated into at least two classes physically, viz., coarse and fine. At hand-filled furnaces this can generally be accomplished without special apparatus, and the stock can be charged into the furnace in accordance with any method the manager may desire, within the limits of the apparatus, which allow great variation, and in this way much can be done to secure uniform working, provided there is sufficient intelligence and vigilance available on the stock-house floor.

BARROWS' METHOD OF CHARGING.

This method was described by Mr. Barrows, Jr., before the Atlantic meeting of the American Institute of Mining Engineers, and may appropriately be called heterogeneous charging.

Assume, for example, that the ore mixture consisted of 25 per cent. of magnetic concentrates, 25 per cent. of fine hematite, 25 per cent. of coarse hematite and 25 per cent. of coarse magnetite, and that a round of ore consisted of 12 barrows.

On this assumption (using the points of the compass for convenience of explanation) the charging would proceed as follows: The coke charge having been lowered into the furnace, then, starting in the north, fill 3 barrows of concentrates side by side, in the northeast quarter; next 3 barrows of coarse hematite, in the southeast quarter; then 3 barrows of fine hematite in the southwest quarter; completing the round with 3 barrows of coarse magnetic ore in the northwest quarter of the hopper. The next round would start in the east with 3 barrows of concentrates above the coarse hematite, next 3 barrows of coarse magnetic ore over the fine hematite, then 3 barrows of fine hematite over the coarse magnetic ore, closing with 3 barrows of coarse hematite over the concentrates. Thus getting every ore into every part of the furnace in regular routine, the coarse and fine ores alternating both as to their vertical and horizontal relation. The main object of this method of filling being to break up the continuity of the gas currents and thus prevent channeling, reduce flue dust and obviate irregularities in general. Mr. Barrows has practised this method with very good success. It is applicable to all hand-filled furnaces, and could be adopted with advantage by all furnaces having to smelt ores differing very much in degrees of fineness.

UEHLING'S METHOD OF CHARGING.

Prior to the advent of the closed furnace tops it was the universal practice to mix the fuel and its burden as much as possible. Every barrow of fuel was invariably followed by a barrow carrying its quota of ore and flux. This method was continued as much as possible after the general adoption of the bell and hopper. At the works in Sharpsville, Pa., where the author first made his acquaintance with the blast furnace, in 1879, the fuel charge consisted of 2 barrows

of block coal of 500 pounds each, and 2 barrows of coke weighing 300 pounds each, a total fuel charge of about 1,600 pounds. The 2 barrows of coal were dumped into the hopper opposite, and the 2 barrows of coke into the gaps left between them. Four barrows, of which each carried its proportion of ore and limestone, were dumped over the fuel and all were lowered into the furnace together, thus mixing fuel and ore as much as possible. After studying "Bell's Phenomena of the Blast Furnace," and particularly "Gruner's Analytical Studies of the Process of Smelting," the author came to the conclusion, based entirely on theoretical reasoning, that it was all wrong to mix the ore and fuel in charging a blast furnace; that, on the contrary, they should be separated as much as possible in order to obtain the best results. The theoretical reasons, both chemical and physical, why this should be so, were fully set forth in a paper published in the "Stevens' Institute *Indicator*," in 1884, and again alluded to in my contribution to the discussion of Mr. Barrow's paper read before the Spring meeting of Mining Engineers at Atlantic City, so that it will not be necessary to repeat them here. Briefly, the method of stratified charging consists in filling the fuel and ore in separate layers. The fuel charge should be as heavy as is consistent with the size of the furnace, forming a uniform strata not less than 2 feet deep. In a furnace over 80 feet high, preferably deeper, the ores should be filled on the fuel in strata, beginning with the coarsest and ending with the finest. The limestone, being coarse, should go on top of the strata of coarse ore. It should be kept, as much as possible, from coming in direct contact with the fuel. Different ores of the same degree of fineness should be charged with regard to their capacity for carbon deposition. This very important phase in the phenomena of smelting was very ably discussed by Mr. F. E. Bachman in a paper read before the Colorado meeting of the American Institute of Mining Engineers, but has not received the attention it deserves. In how far the method of charging above briefly outlined can be carried out in practice, depends on local conditions, which would have to be studied on the premises in each case. It may

safely be said, however, that there are few furnaces, the running of which could not be very appreciably improved by the application of stratified filling. It can be carried out equally well by hand or any of the approved automatic filling devices.

Gas.—The blast-furnace gas is a most important factor in the process of smelting not only inside, but also outside of the furnace. Inside of the furnace it distributes the heat and reduces the ore to the metallic form. How well it performs these functions can always be ascertained from its temperature and chemical analysis. The first symptoms of irregularities in the process of smelting manifest themselves in the gas. A continuous record of the CO_2 would be of the greatest value to the observant blast-furnace manager. The continuous autographic record of the gas temperature has been found by those who give it attention to be an invaluable aid in diagnosing irregularities in the working of the furnace.

Every furnace man knows that a hot top is indicative of a cold bottom. This will be readily understood from the fact that 100° of heat in the escaping gas is equivalent to over 4·25 per cent. of the heat generated by the fuel burned at the tuyeres. Thus, an indirect fuel loss of from 10 to 15 per cent. may easily take place unnoticed until four or six hours later sharp cinder and inferior iron reveals the fact that something went wrong.

In addition to revealing internal conditions of the furnace, the autographic gas temperature record indicates the charges that go into the furnace, both as to time and number, and is, therefore, a most valuable check on the stock-house operation.

In a paper, entitled "The Blast Furnace as a Power-Plant," the author endeavored to show by simple process of calculation that, under conditions of best average fuel consumption, viz., 2,000 pounds of coke per ton of iron, and proper treatment and utilization of the gas, there would be a surplus of at least 800 horse-power per ton of iron produced per hour. Or, in other words, a blast furnace of a daily capacity of 250 tons, or, in round numbers, 10 tons per

hour, should have a surplus of gas over and above all furnace requirements, sufficient to generate 8,000 horse-power in any of the available types of large gas engines. Other investigators, notably Mr. B. H. Twait, who is the pioneer in the field of direct utilization of blast-furnace gas in the gas engine, have come to similar conclusions.

Since publishing the above calculations, the author has had opportunity to investigate the blast-furnace gases at a number of the large iron and steel plants, and has found that his figures were very conservative; that from 1,000 to 1,200 horse-power is nearer the actual surplus power that should be available.

In view of these facts, and the practically more weighty fact, that on the continent of Europe, especially in Germany, there is scarcely a furnace plant where not from several to many thousand horse-power are generated by blast-furnace gas direct, is it not strange that, with one laudable exception, nothing at all has been done to save the enormous waste now going on because of the irrational application of the blast-furnace gas?

From 45 per cent. to 50 per cent. of the heat value of the fuel used in the process of smelting in the blast furnace is contained in the escaping gases, of which 35 per cent. should be sufficient to heat the blast and produce the power to run the furnace and all its mechanical accessories. In spite of this enormous theoretically demonstrable surplus heat energy, the fact remains that, at the majority of the blast-furnace plants, hundreds of tons of coal are burned annually to assist the gas in generating the necessary steam for the power required, and it is the exception rather than the rule that the desired blast temperature can be regularly obtained from the stoves, notwithstanding the fact that both stoves and boilers have from time to time been increased both in size and number. The sole reason of this deplorable condition is due to the fact that the uncleaned gas cannot be efficiently utilized. It is just as irrational to burn the impure gas as it would be to attempt to burn coal mixed with all the slate and rock that is dug and raised with it from the mine.

The partial purification employed at the majority of plants in the dry way is based on irrational methods and carried out by primitive and inadequate means, and rarely more than the coarsest of the flue dust is separated from the gas. The attempts at washing are generally carried out by half-way methods, which, although they remove much of the finer dust, are liable to contaminate the gas to such a degree with moisture that the harm overbalances the good accomplished.

The subject of gas purification is too vast to do more than allude to it at this time. I consider it the most important problem before the blast-furnace manager and engineer to-day. Even if we leave out of sight the value of the surplus gas for power purposes, the saving in extra boiler and stove equipment, in wear and tear on the latter, in time lost directly and indirectly because of stoppages for cleaning, inadequate steam and heat, coal burned, and cost of labor for cleaning stoves and boilers, etc., etc., would more than justify the cost of a gas-washing equipment that would properly cleanse the gas.

LONG-DISTANCE LINES IN FRANCE.

The British consul at Lyons states that the transmission of electric power over considerable distances is developing, and it is stated that 3,000 horse-power is to be transmitted from the Alps, distant 100 miles from Lyons, for the working of the tramway company. The British vice-consul at Grenoble reports that a considerable quantity of electric power is still to be purchased in that district at a cheap rate for the purpose of establishing manufactories of all kinds.

UTILIZATION OF WASTE COAL.

The greater care now exercised in utilizing the output of anthracite coal is shown in the saving and marketing of the small sizes, which were formerly thrown away. In some collieries the proportion of these small sizes, which are used chiefly in making steam, runs up to 40 per cent. of the total shipments. It is evident also in the working over of the old culm banks, from which a considerable quantity of merchantable small coal is obtained. The shipments from the washeries, in fact, have been over 2,000,000 tons in the past two years. It is not impossible that, in a few years more, even the dust, or culm, will be saved and utilized in making power-gas, or in generating electricity at or near the mines, for transmission to points where it is needed.—*Eng. and Min. Jour.*

CHEMICAL SECTION.

Stated Meeting, held Thursday, November 10, 1904.

The Sulphur Dyes.

By J. Merritt Matthews, Ph.D.,
Lecturer on the Chemistry of Textiles and Pottery, Franklin Institute.

There has probably been no branch of chemical research which has yielded more abundant fruit during the past fifty years than that relating to the production of dyestuffs. It is not my intention in this paper to go into the general development of this subject, as that would require a far too lengthy discussion in itself, so I will limit my remarks to the consideration of one of the latest progressive movements dealing with the manufacture and use of the synthetic dyestuffs. By this I refer to the, comparatively recently introduced "sulphur dyes," as they are now commonly referred to.

The original representative of these colors was discovered a number of years ago, in 1873, by Croissant and Bretonnière, and it was given the name of "Cachou de Laval." It was prepared in rather a peculiar manner by the fusion of organic vegetable matter, such as sawdust, etc., with sodium sulphide and sulphur. The resulting product was a porous, lumpy mass of a brownish-black color and readily soluble in water, and decomposing in moist air with the liberation of some sulphuretted hydrogen. It was found that unmordanted cotton could be dyed by this substance a brown color, though the dyestuff, it is true, had but slight tinctorial properties compared with the other artificial dyes, yet the color obtained with it was very fast to washing. It was on account of its fastness that the new coloring matter received a considerable amount of attention. The general method of applying the dyestuff was to boil the cotton material in a solution containing the coloring matter together with a rather large proportion of common salt. This was for the purpose of forcing on the fiber more color, as otherwise it took a very large proportion of the dyestuff to produce any

depth of color. Even under these conditions, however, the dyestuff does not exhaust from the first bath to any great degree. By after-treating the dyed color with a solution of potassium bichromate, the intensity of the color is somewhat enhanced and the general fastness of the dyestuff is improved. By a similar after-treatment of the color with bluestone or copper sulphate, the fastness of the dyeing to light appears to be somewhat increased.

It was also found that cachou de Laval when dyed on cotton acted as a mordant towards a large number of other coloring matters, such as most of the common basic dyes, the vegetable dye-woods, and the alizarine dyes. The shades obtained with the basic dyes, however, are not as fast to washing as the original cachou de Laval, also those with the vegetable dyewoods are not so fast to light; but the shades obtained in conjunction with the alizarine dyes are as a rule fast to both washing and light.

Owing to the small tinctorial powers of cachou de Laval, it never became of much commercial importance in dyeing. It was looked upon chiefly as a curiosity among the artificial dyestuffs, particularly on account of its peculiar method of manufacture.

A number of years passed before the sulphur dyes received any further development. It was not until about 1893 that the French chemist Vidal publicly announced his discovery of a black sulphur dyestuff wich he called Vidal black. This coloring matter was made by fusing para-amido-phenol with sulphur. The product obtained was of uncertain composition, but was found to yield black colors on unmordanted cotton, and was especially characterized by its great fastness. The dyestuff, however, was liable to decomposition on exposure to the air, and presented certain practical difficulties in dyeing so that at first it was not received with much favor. A number of years passed in the development and perfection of this coloring matter and a study of its properties and possibilities, until it had passed beyond the stage of experiment and finally attained commercial success. This led the attention of other dyestuff chemists, especially those of the large German color

factories, to the investigation of the sulphur dyestuffs, with the result that great activity was soon displayed in the preparation of new colors, and the purification and modification of those already known. A large number of these dyes have appeared in trade during the past five or six years, and the range of colors has been so extended as to include various shades of black, brown, blue, green, olive, yellow, and orange colors; a red color among the sulphur dyes is still lacking, the nearest approach being the so-called orange, and certain very red shades of brown. All of these colors are applied in about the same manner and are only used on cotton, giving shades which are very fast, especially to washing and acids, and on this account are very desirable products.

The sulphur colors usually appear in trade in the form of blackish lumps, which are hygroscopic and rapidly deteriorate on exposure to the air, especially in the presence of moisture. On this account the dyestuff should be used up as soon as possible after the package is opened. Recently, however, some of these dyes have appeared in the form of dry powders and are not so hygroscopic, being mixed with some suitable drier, and consequently are not so liable to deteriorate. The manufacturers also seem to be preparing these dyes in a much purer and more concentrated form so that their tinctorial power is considerably increased. The sulphur dyes nearly all smell more or less of sulphuretted hydrogen, especially when moistened or dissolved in water; they also, as a rule, contain more or less sodium sulphide.

Some of the sulphur dyes may be dyed directly on cotton with nothing but the solution of the coloring matter; in other cases, however, a considerable amount of sodium sulphide must be added to the dyebath for the purpose of bringing the dyestuff into proper solution; there is also added some soda ash for the purpose of correcting any hardness which may be present in the water and which would cause a precipitation of the coloring matter. In general these dyes are applied in about the same manner, as regards the manipulation of the cotton materials, as when other dyes are employed. Care must be taken, how-

ever, in most cases, not to have any copper or brass fitting present in the dyeing vats, as the dyestuff is decomposed by these metals; iron and lead, however, may be used without danger. Some of the dyes require an after-treatment with certain metallic salts, especially potassium bichromate or copper sulphate, in order to yield the full development and fastness of the color. In their general fastness they far surpass the other colors available for cotton dyeing, and are comparable in fastness to indigo and aniline black. They are especially suited to the dyeing of material contained in cotton and woolen fabrics, where the cotton is dyed first and the wool is afterwards dyed in acid baths, as these colors will stand the treatment with hot acid baths. The dyestuff does not cause any injury to the cotton fibre, though the dyed goods should be carefully washed in order to eliminate all excess of sodium sulphide, the retention of which by the fibre would eventually cause a weakening; but beyond this, the dyestuff itself does not weaken the goods. One drawback to these colors, however, is that in dyeing them the cotton is liable to become somewhat harsh to the feel, although the fibre may be softened by suitable treatment with oil, or soap baths. The sulphur blacks are especially adapted for the dyeing of fast blacks on hosiery, as also are the brown colors, as the dyestuff stands the repeated washings and the effect of the acid perspiration to which the color of hosiery is subjected.

Correspondence.

THE PROPOSED COMBINATION OF THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY WITH HARVARD UNIVERSITY.

TO THE EDITOR OF *The Journal of the Franklin Institute:*

Sir:—In connection with the proposed combination of the Massachusetts Institute of Technology with Harvard University, the following authoritative statement of foreign opinion (translated from *Zeitschrift des Vereines Deutscher Ingenieure* of September 24, 1904) is of interest:

"At a meeting of the Union of German Engineers, held at Munich, September 12th, with the participation of thirty eminent representatives of technological schools and universities, as well as of other schools and of industries, the following resolutions were adopted:

"(1) It is not advisable, so far as can be foreseen, to attempt to meet the need of new technological schools by the addition of technological faculties

to universities, but rather by the establishment of independent institutions; for the technological schools would be hindered in their independent development by attaching them to universities. This separation should not, however, impede the welcome development of intellectual good-will between the two institutions. The attachment to universities would also in no way involve economies of consequence.

"(2) The Union of German Engineers stands now, as before, by its expression of 1886, as follows:

"'We declare that the German engineers have the same needs and will be subjected to the same judgment as to their general culture as the representatives of other professions based on higher scientific education.'

"In this view we rejoice as the conviction more and more gains ground that a considerably greater significance is to be attributed than before to mathematical and natural science as a means of culture. Knowledge of these branches is becoming more and more an indispensable constituent of general education. The predominantly linguistic education now received by the majority of our gymnasium graduates does not satisfy the demands which must be made on the leading classes of our people, in particular, in respect to the increasing significance of economic questions."

TECHNOLOGICAL GRADUATE.

Book Notices.

De Laharpe. Notes et Formules de l'Ingenieur et du Constructeur-Mechanicien. By a committee of engineers of the Ecole Centrale and the Ecole des Arts et Métiers. Fourteenth edition, revised, corrected and considerably enlarged, containing 1,350 illustrations, followed by a technical vocabulary in French, English and German. Paris: E. Bernard. 1,800 pages (4½ x 7 inches). 12f. 50.

The full title indicates that this is a reference book for engineers covering the matter usually found in mechanical engineers' reference books published in this country, with the addition of some of the data collected in similar works devoted to civil engineering. The scope of the work is further extended by the introduction of data on several branches of industrial technology.

The volume is somewhat awkward to handle, due to its thickness, and its appearance is marred by the display of advertisements on the leather cover and sides. These features, however, are probably due to the effort to produce an extensive work at a minimum cost.

The source of the subject-matter should be a sufficient guarantee of its excellence, but in some instances a better selection could have been made. The section on springs is a case in point: Here fifteen pages are devoted to a discussion of elliptic and some unusual forms of helical springs, with tables of carrying capacity and deflection, but the ordinary helical spring of round wire, which is perhaps more widely used than any other form, is not mentioned.

The copious index and the technical vocabulary at the end of the volume are particularly valuable features to the engineer who desires to consult foreign practice.

In an insert the publishers extend the usual privilege to those who have purchased a previous edition of receiving the latest at a cost of 6f. 25 on the return of the old copy.

L. E. P.

Franklin Institute.

[*Proceedings of the Annual Meeting, held Wednesday, January 18, 1905.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, January 18, 1905.

VICE-PRESIDENT WASHINGTON JONES in the chair.

Present, 76 members and visitors.

The annual Report of the Board of Managers, and Appendices embracing the reports of the Committees of the Board and the Institute, the Sections, and the Trustees of the Elliott-Cresson Medal Fund, were presented and, on motion, were formally accepted.

The Chairman then introduced Mr. St. John Clark, General Inspector of Designs of the New York Rapid Transit Commission, who gave an extended account of the plan and method of construction of the New York Subway.

Mr. Clark was followed by Mr. F. R. Slater, principal Assistant Engineer to the Electrical Director of the Interborough Rapid Transit Company, who gave a description of the electrical power and light equipment of the Subway. Both papers were profusely illustrated.

Mr. Fred. E. Ives, of New York, followed with a communication describing "A New Form of Diffraction Grating for the Spectroscope," in which he described a method that he had devised for making replicas of diffraction gratings, possessing a degree of accuracy approximating that of the originals, which made it possible to furnish students in spectroscopy cheaply with an apparatus of this character of a refinement hitherto unapproachable.

Mr. Ives' invention was referred to the Committee on Science and the Arts for further investigation.

The speakers of the evening were tendered a vote of thanks.

The Tellers of the election made their report of the result of the annual election, held this day between 4 and 8 P.M., whereupon the Chairman reported the following members elected, viz.:

For President	(to serve one year)	JOHN BIRKINBINE.
" *Vice-President*	(" three years)	WASHINGTON JONES.
" *Secretary*	(" one year)	WM. H. WAHL.
" *Treasurer*	(" ")	SAMUEL SARTAIN.
" *Auditor*	(" three years)	WM. H. GREENE.

For *Managers* (to serve three years).

EDWIN S. BALCH,
WALTON CLARK,
THOS. P. CONARD,
CHAS. HENRY HOWSON,
LOUIS E. LEVY,
CHAS. LONGSTRETH,
ISAAC NORRIS,
COLEMAN SELLERS.

For *the Committee on Science and the Arts* (to serve three years).

A. W. Allen,	W. C. L. Eglin,	Geo. P. Scholl,
Hugo Bilgram,	E. Goldsmith,	E. Alex. Scott,
Amos P. Brown,	Lewis M. Haupt,	Coleman Sellers,
Frank P. Brown,	Lucien E. Picolet,	Harrison Souder,
W. W. Canby,	C. J. Reed,	H. W. Spangler,
Kern Dodge,	Jas. S. Rogers,	A. H. Stewart,

D. Eppelsheimer, Jr., Martin I. Wilbert.

The meeting passed a vote of thanks to the Tellers.

Adjourned.

Wm. H. Wahl,
Secretary.

Report of the Board of Managers for the Year 1904, With Appendices Embracing the Annual Report of the Various Committees and Sections.

Presented at the Annual Meeting of the Institute, held Wednesday, January 18, 1905.

To the Members of the Franklin Institute:

The record of the eighty-first year of work of the Franklin Institute, as presented in detail by the accompanying reports of the Officers, Chairmen of Committees and of Sections, shows continued interest in all branches. These reports, which are briefly summarized in the following statement, emphasize the amount of the gratuitous work of members, which the Board appreciates and is gratified to acknowledge.

Endowment.—The Board realizes the generosity of those who have contributed to the funds in the hands of the Trustees, now amounting to $90,000, and of those who have bequeathed to the Institute, property or money, which will ultimately add probably $60,000 to the permanent fund. But the total assets of the Institute, which are, or which may be, available for its maintenance, are far from sufficient to be considered as a recognition of the service which the Franklin Institute has rendered to the advancement of Science and the Mechanic Arts.

During the year efforts have continued to obtain sufficient money to secure better accommodations for our unexcelled technical library, and to increase the invested fund, so as to permit of extending the usefulness of the Institute. Some of these overtures were unfortunately interfered with by premature publicity given to them, although such publicity was evidently presented in a spirit of good-will.

Your Board, which you have continued in office, will endeavor to encourage the co-operation of those whose financial ability may make it possible to overcome the disadvantages under which the Institute work must be prosecuted.

Although located in Philadelphia, the Institute's influence and work is world-wide, and its investigations, made without cost, have been for individuals, the City, the State and the Country, hence, an ample endowment would not be merely the advancement of a local institution.

The Library of technical literature, numbering 58,000 volumes, and nearly as many more pamphlets, charts, maps, etc., is the Institute's chief asset, and the rapid increase in publications demands constant additions and larger outlays for maintenance.

The increase of 2,400 titles during the past year, while gratifying, has not kept the Library up-to-date, and binding, rebinding, indexing, etc., have been curtailed for want of ample funds.

The Journal has been well supplied by papers read at ten meetings of the Institute and thirty-four meetings of its sections; and 546 foreign and domestic technical periodicals regularly received, mostly in exchange for the *Journal*, indicate the esteem in which it is held.

The Meetings of the Institute and Sections and the two courses of popular lectures have been well attended, and much interesting information disseminated. The services rendered by those who presented papers, or delivered lectures, are gratefully acknowledged.

The Committee on Science and the Arts.—Thirty-one medals and awards of merit were granted by the Committee on Science and the Arts in disposing of forty-three cases. An equal number of pending cases suggests the activity of this committee, which by unselfish devotion has helped many meritorious inventions with deserved recognition, or by friendly counsel discouraged misguided inventors.

Membership.—No radical change is indicated by the roll of members, numbering about 1,600, the additions practically offsetting the withdrawal losses by death, etc.

In the absence of sufficient endowment the support of the Institute falls mainly upon its members, and a liberal increase in membership is the immediate method of enlarging the influence and augmenting the usefulness of the Institute.

Your individual attention is directed to the desirability of promptly paying annual dues. In apportioning the income for each year the Board endeavors to utilize it to best advantage, and default in dues works serious disturbances to its administrative plans.

Schools.—Four hundred and seventy-four students received instruction during the year in the schools connected with the Institute, and under the supervision of the Committee of Instruction. Of these 349 are in the drawing school, 87 were students of machine design and 38 studied naval architecture. The attendance was less than in 1903, when the limited space available was over-crowded.

FINANCIAL STATEMENT FOR 1904.

Balance on hand January 1, 1904	$371 78
Receipts in 1904	26,237 81
	$26,609 59
Payments in 1904	24,554 51
Balance on hand January 1, 1905	$2,255 08

The Permanent Endowment Funds of the Institute, January 1, 1905, are $140,855.95, an increase in 1904 of $51,000.

The action of the Institute in promoting the introduction of the Gill School City System of Civic Education into the public schools of Philadelphia resulted in eliciting the unqualified endorsement and earnest advocacy of the movement from the public press, and in enlisting the active support of a very considerable number of our leading citizens. The School City movement has thereby been brought up to a point where its further progress is largely dependent on the official action of our municipal school authorities.

During the past year the Institute has suffered the loss of a number of active and prominent members by death. The following list of names of deceased members is hereto appended, although it is probably not entirely complete:

Edward W. Clark, Luther L. Cheney, S. Lloyd Wiegand, Henry M. Boies, Howard White, Jr., William Weightman, Samuel Wetherill, Henry George Ormsby, Col. A. M. Miller, U.S.A.; T. A. Mackinnon, Morton McMichael, Thomas L. Luder, Dr. B. B. Gumpert, Dr. Thomas M. Drown.

By order of the Board,

JOHN BIRKINBINE, *President.*

REPORT OF THE LIBRARY COMMITTEE FOR THE YEAR 1904.

To the President and Members of the Franklin Institute:

The Committee on Library respectfully submits the following annual report:

The contents of the Library have been increased during the past year by 2,397 titles. In 1903 the accretions numbered 4,924, but the present falling off is due almost entirely to a great reduction in the number of pamphlet additions, which amounted to 662 in 1904 as against 3,179 in the preceding year. Pamphlets are obtained almost exclusively as gifts, many being sent in with the view of their inclusion in a permanent repository; others as contributions from friends of the Institute. It is in this latter respect that we have this year been less fortunate than in the preceding twelve months, the accretions of pamphlets from general sources remaining fully up to the average.

The additions during 1904 comprised:

1,174 bound volumes.
517 unbound volumes,
673 pamphlets,
1 chart,
1 photograph,
31 drawings.

These accretions were derived as follows:

115 through the Bloomfield Moore Fund,
30 " " Memorial Library Fund,
48 " " M. Carey Lea Fund,
50 " " James T. Morris Fund,
20 " " general Library appropriations,
91 " " binding of periodicals,
64 " " *Journal* of the Institute,
17 " " exchange of duplicates,
83 " an old exchange account,

and the remainder through deposits from the Federal and State governments, through contributions from societies and institutions at home and abroad and through gifts from individual donors.

The Ogden N. Rood Donation.—Of the gifts from individuals, a most welcome and valuable addition to the Library was that made by Mrs. Rood, widow of the late Ogden N. Rood, Professor of Physics at Columbia University, who died in 1903. Mrs. Rood's gift comprises the following important items:

Annalen der Physik und Chemie—
Poggendorff series, Vols. 1 to 160, 1824 to 1877.
Wiedemann series, Vols. 1 to 69, 1877 to 1899.
Drude series, Vols. 1 to 9, 1900 to 1902.
Beiblätter, Vols. 1 to 26, 1877 to 1902.
Fortschritte der Physik, Vols. 1 to 57, 1845 to 1901.
Verhandlungen der physikalischen Gesellschaft, 1888 to 1902.
American Journal of Science, 1860 to 1902.

A number of unbound volumes of these periodicals are being bound and will shortly be made accessible for reference.

Through the generosity of Mr. Alfred C. Harrison it has become possible for the Committee to complete the set of specifications of United States Patents without expending any of its regular appropriation in that direction. These reports were five years in arrears and Mr. Harrison expressed his readiness to defray the cost of purchase and gave the sum of $216 for the purpose. These important documents will now be up-to-date and will include the specifications of the year 1904, most of which are still to be issued.

Other considerable gifts of books and pamphlets were afforded to the Library by Drs. Harry F. Keller, William H. Greene, Walter N. James; Messrs. George S. Barrows, John E. Carter, E. P. Cowell, W. J. Donohugh, Morris Ebert, Richard W. Gilpin, Stephen Greene, E. B. Gumpert, Carl Hering, J. Y. McConnell, C. P. Roepper, Samuel Shoemaker, W. Thum, John C. Trautwine, Jr., U. C. Wanner, and by the Crocker-Wheeler Company, the McGraw Publishing Company, Lewis F. Shoemaker Company, and Wilson, Harris & Richards.

The present contents of the Library are as follows:

57,956	volumes (bound and unbound),
42,579	pamphlets,
2,864	maps and charts,
690	drawings and designs,
1,244	photographs,
192	newspaper clippings,
31	manuscripts,
105,556	a total of titles.

The list of periodicals currently received by the Library now numbers 546, an increase of 13 during the past year. The large majority are obtained in exchange for the *Journal* of the Institute, the present increase being all derived from that source.

Binding.—Binding and rebinding were effected during the past year as follows:

92 volumes of completed serials,
11 paper-bound books,
3 rebindings,

106 total.

Three hundred and sixty-four volumes are still in the binder's hands and much further work of this nature is urgently demanded. An expenditure of $500 in this direction could be made with great advantage to the Library. An especially pressing need of this nature is the binding of the sheets of the great mass of British Patent Specifications. The movement, mentioned in last year's report, for an advance in this direction by means of contributions to a fund specially for this purpose was halted by reason of other demands, and the situation remains unimproved.

The Pamphlet Library.—The pamphlet section of the Library remains as yet in a condition leaving much to be desired. The pamphlets are stored on shelves in the south room, on the first floor of our building, where they are well preserved but practically unavailable through lack of proper classification. Many of these pamphlets are of great value as records of important transactions, and as treatises not otherwise published, and to make them accessible for consultation they should be thoroughly classified and represented in the card catalogue of the Library. This work will require the services of a trained assistant for a considerable period of time. An expenditure of some $1,500, covering wages, boxes and cards, would about accomplish this most desirable improvement of the Library.

Increase of the James T. Morris Fund.—Of the various special funds now sustaining the Library, that established by Mr. John T. Morris, in February, 1899, with a foundation of $1,000, and since augmented by several additions of $1,000, has again been enriched by his contribution on December 27th, ult., of another sum of $1,000. The income of this fund has been made available by Mr. Morris for the purchase of books on the subject of mechanics, and this section of the Library is already largely reaping the benefits of his good-will.

Evening Attendance.—The attendance of the Library after business hours in the evening shows a continuance of the falling off noticeable in recent years. The Library was open on 80 evenings during the past year with a total attendance of 238, a decrease of 155 from the preceding year. This condition emphasizes nothing so much as the fact alluded to in our last report, that the location of the Institute in the heart of the business section of the city, while leaving it amply accessible in the daytime, places it far out of the channels of active intercourse after nightfall, and renders it in that respect correspondingly less available for that large class of the community which has only the evening hours at its disposal.

LOUIS EDWARD LEVY,
Chairman.

REPORT OF THE COMMITTEE ON SCIENCE AND THE ARTS FOR THE YEAR 1904.

To the President and Members of the Franklin Institute:

The Committee on Science and the Arts has the honor to submit the following statement of the work done during the year just closed:

To facilitate the work of assigning the applications to appropriate sub-

committees, the personnel of the whole Committee was classified as to professional occupations or trades, and it was found in a general way that the qualifications were distributed about as follows:

Mechanical Engineers, chiefly	15
Electrical " "	9
Chemists or Doctors of Medicine	8
Graphic Arts	3
Geologist and Mineralogist	1
Metallurgist	1
Plumber	1
Pure Science	3
Naval Architects	2
Photography	3
Civil Engineering	2
Insurance	1
General Utility	2
Miscellaneous	6

Many of the members were fully qualified to render good service outside of their specialties and were so assigned. It appears, however, that there is a notable weakness in the section of Civil Engineering, which may be due to the fact that most of the applications are for mechanical devices and relate especially to machinery, steam, electrics or some branch of the Arts or Manufactures, so that this may be more apparent than real as a source of weakness in the Committee.

As will appear in the Appendix, in detail, the total number of cases submitted to the Committee during the past year was 86, of which 50 per cent. were finally disposed of, and of these 38 received advisory reports or awards. Of the 27 medals granted, 5 were for the "Elliott Cresson," 15 for the "John Scott" and 7 for the "Edward Longstreth."

In this connection it may be well to record the fact that the Courts have decided finally the authority of the Franklin Institute to determine and make the award of the Elliott Cresson Medal.

The large amount of disinterested expert service rendered by the members of the Committee cannot be stated in figures, but some idea may perhaps be gained of its distribution by reporting the number of cases on which service was accepted by the individual members, thus:

Four of the members, exclusive of the chairman, could not serve at all.

7	served on	1	case.
11	" "	2	cases.
16	" "	3	"
9	" "	4	"
4	" "	5	"
3	" "	6	"
2	" "	8	"
1	" "	10	"

Changes in the Personnel of the Committee.—It is with regret that the Committee is obliged to report the resignation of four of its efficient and experienced members who find it no longer possible to serve the Institute in this capacity, so that their resignations were reluctantly accepted and the vacancies supplied by the election of new members.

The resignation of Dr. Henry Leffmann, so long and favorably known, left a vacancy filled by the election of Dr. W. J. Williams, of the Frankford Arsenal, Bridesburg, Philadelphia, Pa.

Mr. Wilfred Lewis, one of our most highly esteemed mechanical experts, left a vacancy which will be filled at the next annual election.

The vacancy caused by the retirement of Prof. Edgar Marburg was filled by the election of Mr. A. W. Allen, of the American Bridge Company, Philadelphia, and the resignation of Mr. C. W. Pike was filled by the election of Mr. Richard L. Binder, of Philadelphia, Pa.

It is the painful duty of this Committee also to report the loss by death of one of its oldest, most esteemed and ablest members, Mr. Luther L. Cheney, whose conservative judgment and long experience have been of the greatest service to the Committee and the Institute, and have endeared him to the membership as a warm personal friend.

Meetings.—During the year 11 sessions were held, of which 10 were regular and 1 was special. There was an average attendance of 20 members, the highest being in April, when there were 30 present; and the lowest in September, when there were 16 present. An analysis of the attendance shows the following interesting statement:

Of the total membership of 60—

11	were absent	from all meetings,	
2	members attended	once,	
9	"	"	twice,
5	"	"	three times,
7	"	"	four times,
4	"	"	five times,
2	"	"	six times,
7	"	"	seven times,
7	"	"	eight times.

In closing this report the chairman desires to extend his grateful thanks to the members of the Committee on Science and the Arts, as well as to the efficient Secretary of the Institute, for their active co-operation and cordial support in the conduct of its affairs during the past year.

Respectfully submitted,

LEWIS M. HAUPT,
Chairman for 1904.

PHILADELPHIA, PA., January 2, 1905.

APPENDIX.

DETAILS OF THE COMMITTEE'S WORK IN 1904.

Number of cases pending on December 31, 1903		38
Number of cases proposed in 1903:		
(*a*) By application	33	
(*b*) By reference from the Institute	9	
(*c*) By vote of the Committee	5	
(*d*) By vote of Sections	1	
Total number of new cases in 1904		48
Total number of cases before Committee in 1904		86

Total number of cases finally disposed of in 1904,	43	
Of which there were: Adopted,	40	
Dismissed or withdrawn,	3	
Cases pending December 31, 1904	43	
		86

The forty-three cases disposed of were determined as follows:

Award of Elliott Cresson Medal	5
Award of John Scott Legacy Premium and Medal	15
Award of Edward Longstreth Medal of Merit	7
Award of the Certificate of Merit	4
Reports made advisory	7
No awards	2
Cases dismissed or withdrawn	3
Total	43

REPORT OF THE COMMITTEE ON MEETINGS FOR THE YEAR 1904.

To the President and Members of the Franklin Institute:

The Committee on Meetings, with the assistance of the Secretary of the Institute, has arranged the programs of the ten meetings held during the past year. In performing this task the Committee has sought to secure subjects of general public interest, and, judging from the generally good attendance, its efforts in this direction have been reasonably successful.

As was noted in last year's report, the growing importance of the work of the Sections renders it increasingly more difficult for this Committee to retain for the monthly meetings the conspicuous place they used to occupy before the institution of the Sections, and as then stated it will continue to be the policy of the Committee "to reserve the meetings as far as possible for the presentation and discussion of subjects of general interest and importance."

Respectfully yours,

WASHINGTON JONES,
Chairman Committee on Meetings.

PHILADELPHIA, PA., January 2, 1905.

REPORT OF THE COMMITTEE ON PUBLICATIONS FOR THE YEAR 1904.

To the Board of Managers.

GENTLEMEN: The Committee on Publications has nothing of special importance to communicate with reference to its operations during the past year. With the appropriation made by the Board of Managers, it has been able to continue the publication of the *Journal*, and to maintain its respected position. The amount of material offered for publication by the Sections, the Institute meetings and the several Committees, has been ample to supply the Committee's requirements. The circumstance that the *Journal*, for a number of years, has been in fact what its name implies, the Journal of the Franklin Institute, should be highly gratifying to the Managers and the

members, indicating as it does, a steady maintenance of the scientific activities of this Institute.

HARRY W. JAYNE,
Chairman of Committee on Publications.

PHILADELPHIA, PA., January 2, 1905.

REPORT OF THE COMMITTEE ON INSTRUCTION FOR THE YEAR 1904.

To the Board of Managers.

GENTLEMEN: The interest shown by the members of the Institute in the popular lecture courses given in co-operation with the Central Branch of the Young Men's Christian Association has been quite satisfactory to the Committee, the attendance at the lectures having been excellent. As heretofore, the services of the eminent lecturers who have contributed to make the Committee's work successful, have been given without compensation, and the thanks of the Board are due to them.

The schools have been well patronized, although the number of pupils enrolled has fallen off somewhat from the high figures of the previous year. The comparative data for the years 1903 and 1904 make the following exhibit:

	1903.	1904.
Drawing School	445	349
School of Machine Design	107	87
School of Naval Architecture	85	38
	637	474

With the sanction of the Board, the important step was taken, during the past year, of increasing considerably the teaching force, by the appointment of a number of eminent specialists as professors and lecturers on special subjects. The change thus instituted has already begun to exhibit its advantages in giving substantial assistance to the various branches of the Institute's activity.

Respectfully submitted,

WM. H. WAHL,
Chairman of Committee on Instruction.

ANNUAL REPORT OF THE COMMITTEE ON ELECTION AND RESIGNATION OF MEMBERS FOR THE YEAR 1904.

To the Board of Managers of the Franklin Institute:

The Committee on Election and Resignation of Members respectfully submits the following membership figures for the year 1904.

The Committee has continued its special systematic efforts to obtain new members.

The Committee's work, supplemented by that of several members who have from time to time presented a new name, and by the very considerable assistance rendered by Mr. Robert C. H. Brock, member of the Board, has been enabled to place on the rolls the names of 101 new members. The losses through death, resignation and non-payment of dues are noted in the accompanying schedule, showing that, numerically, the membership remains about

the same as at the close of 1903. The Committee again urges the membership in general to participate in the work of increasing the numerical strength by inducing new persons to join. The result of the presentation of one new name by each member is easy to calculate.

The membership at the close of 1903 was	1,605
New members secured in 1904	101
	1,706
Loss by death, resignation and non-payment of dues	109
Members at close of 1904	1,597

ALEXANDER KRUMBHAAR,
Chairman.

PHILADELPHIA, January 2, 1905.

REPORT OF THE COMMITTEE ON SECTIONAL ARRANGEMENTS FOR THE YEAR 1904.

To the Board of Managers:

Your Committee on Sectional Arrangements respectfully reports that during the year 1904 the Sections of the Institute held thirty-four meetings, nearly all of which were devoted to the consideration and discussion of subjects of strictly technical or scientific interest. The pages of the *Journal* afford the best evidence of the value of the work thus accomplished.

The Committee is pleased to be able to report that the interest of the members in this branch of the Institute's activity is well maintained. The report of the secretaries is appended hereto.

JAMES CHRISTIE,
Chairman Com. on Sectional Arrangements.

PHILADELPHIA, January 2, 1905.

APPENDIX.

To the Committee on Sectional Arrangements:

The several Sections have had thirty-four meetings during 1904, all being joint sessions of the entire Section body. In respect of attendance and the general character of the subjects discussed, the past year will compare favorably with any of its predecessors. The *Journal* has been enriched by numerous contributions of value from this source.

Some modification of present methods will be introduced in 1905, for the purpose of keeping more prominently before the members the idea of the separate organization of the individual Sections, which, naturally, has been forced more or less into the background by the placing of all the special routine work hitherto done by each Section in the hands of an Executive Committee appointed by the Committee on Sectional Arrangements. With the restoration of these functions, it is believed that the only serious criticism that has been brought against the "joint session" plan as now in vogue, will be met satisfactorily.

WM. H. WAHL,
for the Secretaries.

PHILADELPHIA, January 3, 1905.

Committee on Science and the Arts.

Abstract of proceedings of the stated meeting held Wednesday, January 4, 1905.

PROF. LEWIS M. HAUPT in the chair.

The following reports were adopted:

(No. 2312.) *Improved Cap-screws and Bolts.*—The Cleveland Cap-screw Company, Cleveland, O.

ABSTRACT: The cap-screws made by applicant company are intended to be used for the same purposes and in the same manner as cap-screws have heretofore been used. The novelty contained in these products consists in the fact that the inclosing together of the head and body of the screw is done electrically, die-drawn stock prepared for the purpose being the material used, and the heads made to conform to the United States or Franklin Institute standard heads.

(The details of the several processes of manufacture are interesting, but cannot well be abstracted. The report will in due course be published in full.)

The Committee made a number of tests—tensile and torsional— of samples of these cap-screws, with results that were quite satisfactory, confirming substantially those published in the descriptive pamphlets issued by the manufacturers.

The report recommends the award of the John Scott Legacy Premium and Medal to David T. Kurtz, the originator of the method. (*Sub-Committee:* J. Logan Fitts, Chairman; Charles E. Ronaldson, D. Eppelsheimer, Jr.)

The following reports were considered and referred back to their respective sub-committees for various reasons.

(No. 2331.) *Electric Protective Devices.*—The International Burglar Immunity Company, Philadelphia.

(No. 2345.) *Products of the Flexible Compound Company*, Philadelphia.

The following passed first reading:

(No. 2310.) *A System for Quantitative Calorimetry.*—Dr. Persifor Frazer, Philadelphia.

(No. 2329.) *Knitting Machine.*—Edward Parkinson, Philadelphia.

(No. 2342.) *Hydraulic Letter-copying Press.*—Walter A. Rosenbaum, New York.

(No. 2348.) *Elevator Safety Devices.*—The Standard Elevator Interlock Company, Philadelphia.

PROTEST: The protest of Messrs. Seitz & Barnes objecting to the grade of the award granted to Seitz for his improvement in "Coal loading and screening machinery," was reported back from sub-committee No. 2294, with a favorable recommendation. The report was accordingly amended by the grant of the Edward Longstreth Medal of Merit.

The Annual Report of the Committee for 1904 appears elsewhere. W.

Sections.

[*Abstracts of Proceedings of Stated Meetings.*]

SECTION OF PHOTOGRAPHY AND MICROSCOPY.—*Stated Meeting*, held Thursday, January 5, 1905, 8 P.M. Dr. Henry Leffmann in the chair. Present, 47 members and visitors.

The annual election for officers, which was held, resulted as follows: President, Henry Leffmann; Vice-Presidents, J. W. Ridpath, U. C. Wanner; Secretary, Martin I. Wilbert; Conservator, William H. Wahl.

Dr. J. L. Borsch presented a communication on "A New Bi-focal Lens." Dr. Borsch gave a brief historical sketch of the origin and development of bi-focal lenses, which, he said, had been originally devised by Dr. Benjamin Franklin when he was in Paris, and described an improved lens of this character which he had devised.

A paper by Mr. C. Chester Ahlum, describing the microscopical and chemical differences between sumac and tobacco, was, in the author's absence, read by the Secretary. The subject was illustrated by several lantern slides and microscopic preparations.

Mr. Charles S. Rabineau, representing the Eastman Kodak Company, of Rochester, made demonstrations with a new developing machine for "Velox" paper.

The meeting was closed by an exhibition of miscellaneous lantern slides illustrating various features of the St. Louis Exposition and views taken in the mining regions of Idaho and Colorado. They were described by Mr. W. W. Canby. Mr. Balderston, of Williams, Brown & Earle, gave a demonstration of the various capabilities of the recently acquired microscopic attachment to the Institute's lantern.

On motion, the bi-focal lens of Dr. Borsch, and the "Velox" developing machine, were referred to the Committee on Science and the Arts for investigation.

Adjourned.

M. I. WILBERT,
Secretary.

ELECTRICAL SECTION.—*Stated Meeting*, held Thursday, January 12, 1905, 8 P.M. Mr. Thomas Spencer in the chair. There were present 45 members and visitors.

The following officers were elected to serve for the year 1905: President, Thomas Spencer; Vice-Presidents, W. C. L. Eglin and Charles J. Reed; Secretary, Richard L. Binder; Conservator, Wm. H. Wahl.

The president introduced the speaker of the evening, Mr. C. J. H. Woodbury, American Telegraph and Telephone Company, Boston, who read a carefully prepared paper in which the subject of "Telephone Line Engineering" was treated very thoroughly.

The paper, with discussion thereon, was referred to the Committee on Publication.

The meeting passed a vote of thanks to the speaker.

Adjourned.

RICHARD L. BINDER,
Secretary.